ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind

VOLUME VIII JULY 1949 NUMBER 31

Alum: Medium of history

History has been written from many angles—military, political, economic, commercial, ethical, and so forth—and one might well doubt the possibility of discovering a new approach. Yet though the main threads of the vivid and complex tapestry may have been well and truly traced, the tortuous course of a minor thread may reveal points of interconnection previously overlooked. Mr Derek Spence suspected that the story of alum through the ages might prove to be such a thread, and the doyen of historians of science, Professor Charles Singer, has remarkably vindicated him. In a sumptuous volume recently published[1] Singer has in effect worked his way from ancient Egypt to the modern world by following alum as his Ariadne's clue, and has described his journey in a narrative which provides something entirely novel in the sphere of chemical history—and of history in general. There are innumerable histories of chemistry, of various branches of chemistry, and of metals and minerals, but a folio on the history of a single chemical is something to demand and deserve wide attention: for there are many other minor threads, which, in sum, form much of the colour and much of the strength of the fabric of civilization.

Alum was a fortunate choice for this first experiment in a new approach to chemical history. It is a chemical substance with a past—and the past stretches back to the remote days of the Pharaohs. It is also the only substance, apart from certain metals and gems, that has been obtainable from the earliest times in a state of comparative purity. Further, its main uses—as a mordant, as a styptic, and for the treatment of leather—have remained constant throughout millennia. The thread is thin, but strong and continuous.

The ancient Egyptians, an ingenious and enterprising race, are credited with having built the first ocean-going ships, with which they carried on a flourishing export trade, not only in such sophisticated articles as artificial pearls but in commoner commodities, including alum. They knew how to purify alum, for impurities render it useless as a mordant for bright colours, and a fragment of leather taken from an Egyptian tomb of about 2000 B.C. probably owes its red colour to madder mordanted with alum.

The Assyrians were similarly well acquainted with alum, which they obtained from several localities (Shap Ma'den, Tuz Khurmati, Hamairan, etc.) and used not only as a styptic and for dyeing wool, but for various medical purposes and for tanning. Whether they knew its fire-proofing properties is uncertain, but this particular application of alum was familiar to Aulus Gellius (second century A.D.), who described how one of Mithridates' generals fire-proofed a wooden tower with alum in the war with Rome in 87 B.C. It is possible that alum had been used for fire-proofing some centuries earlier, for when the old temple at Delphi was destroyed by fire, and a new one was to be built, the authorities obtained a gift of 1,000 talents of alum from Amasis, the last native Pharaoh (570–525 B.C.). As Singer observes, the mere carriage of so much alum over seas involved considerable shipping activity, and in fact the whole early history of the alum trade and that of shipping and sea ways are linked together.

In the days of Imperial Rome, alum became a state monopoly in Egypt, and its taxable nature was widely recognized; in A.D. 229 one Aurelius Macrobius is formally described as 'lessee of the alum administration.' The main source of alum was the 'Little Oasis,' 180 miles south-east from Cairo, and the mineral was thence carried to Behnesa, a port on the Nile. From Behnesa it was shipped downstream for local use or for export

[1] *The Earliest Chemical Industry*, by Charles Singer, with a preface by Derek Spence. Pp. xx + 338, with numerous illustrations and coloured plates. The Folio Society, London, 1948. Limited editions, 25 guineas and 10 guineas.

from Alexandria. There are references to the alum monopoly in the celebrated Oxyrhyncus Papyri, a touch of humour being provided by the entry concerning a certain camel-driver who claimed, and obtained, repayment of a toll unjustly exacted from him by some officials of the monopoly.

Through the Dark Ages, when applied chemical knowledge was preserved for the most part by obscure craftsmen, familiarity with alum and its properties was maintained, and the alchemists of Islam observed its resemblance to the vitriols. It next comes into prominence, however, in the thirteenth century, when the elusive Geber mentions it in the first clear account of the preparation of nitric acid and *aqua regia*: 'Take of vitriol of copper one pound, of salpeter ½ pound, of Yemen alum ¼ pound. Extract the water with an alembic at dull red heat. The distillate becomes much more active if you add a quarter pound of *sal ammoniacum*, for the liquid then dissolves gold, sulphur, and silver.' Nitric acid, a substance indispensable to the modern world, thus first appeared upon the chemical scene as a product of alum.

By the fifteenth century the preparation of alum had reached manufacturing dimensions, and a conventional 'alum cauldron' was in use which could be worked continuously. It consisted of riveted copper strips with a cast bronze bottom, and was mounted in stone or brick work and heated by a furnace. The alum-stone or alunite was roasted and weathered, and was then added to boiling water in the cauldron. After about half an hour's continuous stirring with wooden ladles the solid matter was ladled out and a fresh supply added. The process was repeated until the solution was saturated; the liquid was then run off to crystallize for about a week and the mother-liquor was returned to the cauldron. Many of these cauldrons were in use in the alum works at Phocaea (Ionia), owned by the Genoese brothers Zaccaria from about 1275 to 1308. The business seems to have been very profitable, for one of the brothers, Benedetto, gave large sums of money to further his favourite project, the recovery of the Holy Land from the Saracens. A contemporary chronicler says that there were over 3,000 alum workers at Phocaea, a figure which gives an indication of the importance of the industry. A century or so later, two Florentine traders placed an order at Phocaea for over 1,000 tons of alum.

In 1461, alunite in large quantities was found in papal territory, and the Pope, Pius II, having in Giovanni de Castro a man who was expert in industrial alum production, at once attempted to create a monopoly. Within two or three years the papal production of alum required the services of no fewer than 8,000 workmen. The technical side of the business was managed by a partnership (including de Castro) known as the *Societas Aluminum:* later a contract was signed with the Medici—and the alum trade had begun to find itself interwoven with the general political history of Europe. A century afterwards, English privateers found alum ships rich prizes, for Britain had begun to dye her own fabrics and the price of alum had soared. Pope Leo X protested in vain that a ship carrying 12,000 ducats' worth of papal alum had been seized by an English rover and brought into Falmouth for the benefit of the Duke of Suffolk.

So the fascinating story goes on, showing, as Mr Spence remarks in the preface, surprising and ever more intricate relations. 'In the process of tracing the applications of this simple chemical substance,' he says, 'we have repeatedly been astonished to find the threads of our story involved in many great human movements, political, economic, social, technical, scientific, philosophical, religious, and artistic.' The same complexity would no doubt be found in the history of many other substances: but they still await the wide erudition of a Singer. And to produce so luxurious a volume as the present, future scholars must await munificence comparable to that of Peter Spence and Sons Limited, who met the cost of preparation and publication. Such an example of enlightened patronage is worthy to be followed. Professor Singer has brilliantly conceived an original approach to the study of science and civilization, and has made a notable addition to the achievements of British scholarship.

Editor: E. J. HOLMYARD, M.A., M.Sc., D.Litt., F.R.I.C.
Deputy Editor: TREVOR I. WILLIAMS, B.A., B.Sc., D.Phil.
Foreign Editor: J. A. WILCKEN, B.Sc., Ph.D.

Imperial Chemical Industries, Nobel House, Buckingham Gate, London, S.W.1.
Communications to the Editors should be addressed to 26 Dover Street, London, W.1.

Nitrogen metabolism in plants

W. H. PEARSALL

Plants absorb nitrogenous material in comparatively simple form and build it up with carbon compounds into the amino-acids which are the basis of proteins. The mechanism of protein synthesis and breakdown offers innumerable problems to the biochemist, the botanist, and the plant physiologist, and it seems highly likely that the solution of these problems would result in an important integration of many diverse phenomena of plant metabolism.

The building-up and breaking-down of nitrogenous compounds are fundamental parts of the metabolism of plants, because they deal with the production of a group of substances that are the raw materials of living matter—proteins which make up much of the protoplasmic structure; nucleic acid and the nucleotides, associated particularly with the hereditary properties of cells; and pyrrole derivatives, often pigments like chlorophylls, which are an essential part of the metabolic framework. The chemical complexity of these nitrogenous substances is such that it offers to the biochemist innumerable problems, which are of necessity reflected in the material transformations involved in the synthesis and breakdown of the nitrogenous materials. Fascinating as these problems often are, and necessary as their solution is to any proper understanding of the problems of plant nutrition, their interest often draws us away from taking a broad view of the nitrogen metabolism as a whole.

Although the raw material of fact is often the same, the point of view of the botanist or plant physiologist is normally very different from that of the biochemist; in particular it is broader, in that the observer is often more concerned with overall processes and their bearing on the life of plants than with the distinct biochemical mechanisms involved. A morphological or cytological feature is often as important as a chemical one, and each must be fitted into the general picture. The danger here is of over-simplification in the attempt to create a unified picture; it will be ever present in the following pages. I shall attempt to outline what might be described as the biological background of nitrogen metabolism in plants.

PROBLEMS OF PROTEIN SYNTHESIS

When a plant protein is hydrolysed by acid or by enzymes it yields about twenty amino-acids in widely different proportions. One of the problems of the synthesis of proteins is how these varied mixtures of twenty or more amino-acids can be marshalled during synthesis. The evidence seems to be clear that proteins are not random aggregation products of amino-acid condensation, but that the order in which the amino-acids occur in the protein shows constantly recurring features. It is apparent therefore that highly complicated structural difficulties are involved in protein synthesis, and these can be overcome only by supposing that the amino-acids are assembled on an existing and specific structure, such as the protoplasmic protein itself, as a basis. On this basis new material is grafted, as it were, repeating the pattern and maintaining the complexity. Such a process is hardly to be distinguished from growth, and I shall assume that protein synthesis mainly occurs where growth is taking place, or, perhaps preferably, where protoplasmic synthesis is possible.

It is thus natural to examine the data available for the conditions existing in plant growing-points. The development of the new technique of chromatographic identification of amino-acids has made it possible to detect with some certainty the different amino-acids, even in low concentrations. The method has been applied to various plant tissues by Dent, Stepka, and Steward (1947), and by Alsopp (1948). By this means it has been shown that, while mature tissues often contain the great variety of amino-acids expected from protein breakdown, growing tissues commonly contain only a limited selection, of which glutamic acid is most prominent and always present, though aspartic acid often accompanies it. These facts may suggest that the synthesis of proteins in plants is canalized, as it were, through a limited number of amino-acids. On *a priori* structural grounds we might perhaps expect that alanine with glutamic and aspartic acids would represent suitable building stones for many amino-acids. The methods of further elaboration are unknown.

UNIVERSITY OF PENNSYLVANIA LIBRARIES

However this may be, it is not at all difficult to show that the hypothesis of the dependence of protein synthesis upon growth is in large part true. It was shown by Sachs in the sixties of the last century that proteins were quantitatively most abundant in the growing tissues of stem and root and in buds, and of course the germination of protein-rich seeds and the production of new protoplasm in the resultant seedlings must involve, first, hydrolysis of proteins, and then the condensation of new protein in the growing seedlings.

It is necessary to suppose that, in most active tissues, protein metabolism in both aspects is going on all the time, and that we are really dealing with substances continuously being broken down and built up, so that at any moment the amount of protein present in a plant organ is the net result of these two opposing tendencies. As a general rule, therefore, in the mature cell or tissue, where large fluctuations in protein content are not usual, the two processes of synthesis and degradation tend to proceed at more or less equal rates.

It is only recently (with the introduction of the isotopic technique) that this idea of the lability of the tissue proteins has been justified. By using as a tracer the isotope N_{15}, supplied to the plants in the form of ammonium salts, it has been shown that the isotopic nitrogen almost immediately appears in the structure of the amino-acids and proteins. Interchange of nitrogen takes place even in the peptide linkages, so that not only must there be continuous removal and replacement of the α-amino nitrogen of the constituent amino-acids, but also a continual opening of the peptide linkages in the protein chain. These have previously always been regarded as the fundamental part of the protein structure and relatively stable. This reconstitution of the protein may amount to as much as 6 per cent. in 12 hours, and it appears to be more rapid in young leaves than in old. There is, however, a second reason for believing that proteins are continually being decomposed and reassembled. It has been necessary to make use of this idea in order to explain how it is that a large part of the carbon dioxide evolved in respiration comes from protein. A modern explanation first put forward by Gregory and Sen (1937), and by Richards (1938), supposes that carbon chains, derived from carbohydrate in the first place, pass through the 'metabolic pool' and emerge as organic acids (α-keto-acids) to be built up with ammonia into amino-acids and proteins. At the same time, amino-acids resulting from protein breakdown are oxidized to yield ammonia, carbon dioxide, and carbon residues which return to the metabolic pool. As long as carbohydrate is in abundance, the synthetic side of this cycle balances the rate of protein decomposition and amino-acid oxidation, so that little or no change in gross protein content ensues. Nevertheless, using this conception, it is possible to understand how it is that, in the detailed examples studied, respiration rate is mainly dependent on the protein content of the tissue and on the amount of protein synthesis. When the effects of these two factors can be eliminated, there are left certain subsidiary variations associated with the amino-acid and sugar content of the tissues. These also fit in with the general hypothesis.

PHYSIOLOGICAL DRIFTS

In organs such as leaves, the idea of a continual building-up and breaking-down of protein must not only be coupled with the theory of resultant respiratory changes but must also be viewed against a background of continually changing physiological states. The reaction system—protein ⇌ amino-acid—trends towards the left at first, but drifts towards the right as the tissue ages. One of the simplest ways of showing this is by considering the proportion of protein nitrogen present in a tissue such as a leaf at different stages of its existence. This follows a course like that shown in figure 1 for the Swiss Chard (*Beta vulgaris* var. *cicla*), which is amplified from some earlier published work (Pearsall, 1931). The percentage of protein nitrogen is high at first, and falls rapidly to a lower level as the leaf matures, after which it declines much more slowly. When the leaf becomes old, however, there sets in a second rapid decline in protein content, which is finally accompanied by the yellowing of the leaf and, a little later, by its death. Thus there is all through the life of the leaf a slow 'physiological drift,' proceeding at varying rates but resulting in an increased tendency towards protein hydrolysis. For practical purposes, however, we can regard the period of maturity as a steady state in which, as we have seen, the building-up and breaking-down processes are going on at almost the same rate. During the continuation of this steady state it appears (Gouwentak, 1929) that an important factor determining whether protein synthesis ensues in a leaf is whether or not the leaves can gain nitrogen from the roots or from other parts of the plant.

The drifts in physiological condition during the development of the tissue are associated with two other very striking changes in leaf metabolism. In

J

PROTEIN N (MG PER LEAD

BASIC N/NON-BASIC N

F
th
u
re

t
i
n
d
V
t
p
r
f
a
b
f
o
n
d
a
t
c
e
t
s
m
i
h
r

w
m
w

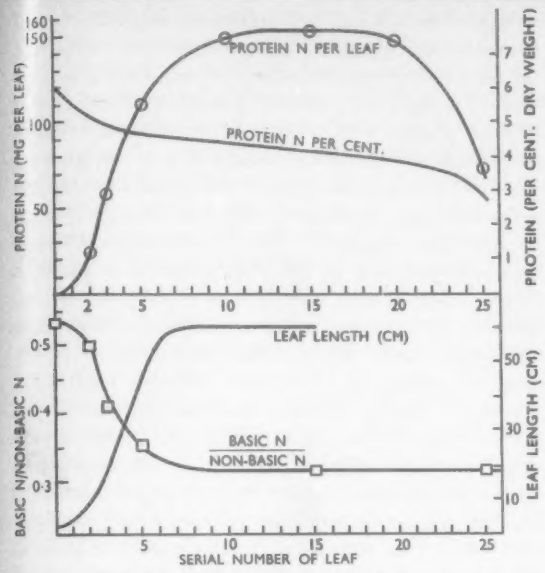

PROTEIN N PER LEAF
PROTEIN N PER CENT.
PROTEIN N (MG PER LEAF)
PROTEIN (PER CENT. DRY WEIGHT)
LEAF LENGTH (CM)
BASIC N / NON-BASIC N
SERIAL NUMBER OF LEAF

FIGURE 1 – *Protein nitrogen as mg per leaf and per cent. of the dry weight in Swiss Chard* (Beta vulgaris *var.* cicla), *with (below) comparable figures for leaf length and for the ratio of basic N to non-basic N in the leaf proteins.*

the earliest stages of leaf growth, when cell division is most rapid, a very considerable part of the nitrogen metabolism is concerned with the production of the nuclear material (e.g. nucleic acid). Very little attention has been directed towards this aspect of leaf metabolism, but it can be shown plainly enough by observing the change in the ratio of basic nitrogen to other nitrogen liberated from the leaf proteins after their breakdown by acid hydrolysis. This is usually brought about by boiling the leaf material with 6N-hydrochloric acid for 24 hours, resulting in the complete hydrolysis of the proteins. The fall in the proportion of basic nitrogen which results as nuclear division slows down is well shown in figure 1 for Swiss Chard, and it is known that a similar change in the proportion of basic nitrogen is observed in the soluble compounds present in very young leaves. It is evident that the rate of protein synthesis is extremely high during and immediately after the stage of nuclear division (see figure 1), but this matter has been directly studied only in bacteria, in which, using spectrographic methods, Caspersson has shown that there is a correlation between the rates of formation of nucleotides and of protein.

A second change in leaf metabolism follows when cell extension is becoming well marked. The metabolism of the leaf changes over from one which is mainly concerned with nitrogenous substances—proteins and nucleotides—to become a form of metabolism principally concerned with carbohydrates, at first those of the cell walls and glycosides, but subsequently also those formed in green tissues by photosynthesis. In fact, the same type of change may be observed microscopically in the development of the single cell, as it passes from the dividing stage in the meristem with a very thin wall, a large nucleus, and dense protein-staining contents, to the elongating cell, rapidly developing a thicker and more differentiated cell wall, and believed to have a smaller ratio of nucleus to cytoplasm. Similar changes develop during the growth of an algal population (e.g. *Chlorella*). The period of rapid cell-division or exponential growth is one of protein synthesis, and evidently of nuclear synthesis also. As growth slows down, the cells increase in size, and carbohydrate accumulation becomes prominent. Still later, as the cells age, hydrolysis ensues both in the reserve carbohydrate and in protein, so that a considerable proportion of the materials present in the cells may finally escape to the surrounding

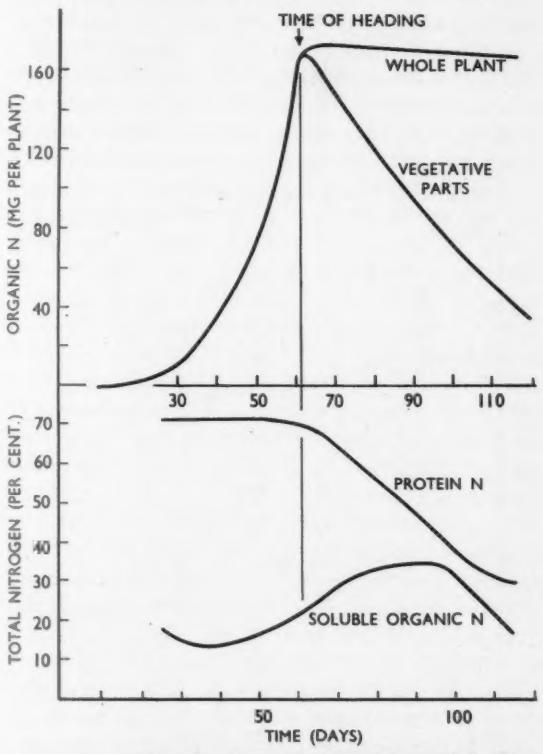


FIGURE 2 – *Organic nitrogen in wheat plants: (above) as mg per plant at different dates, showing the loss of nitrogen from the vegetative parts; (below) percentages of protein and of soluble organic nitrogen in the vegetative parts.*

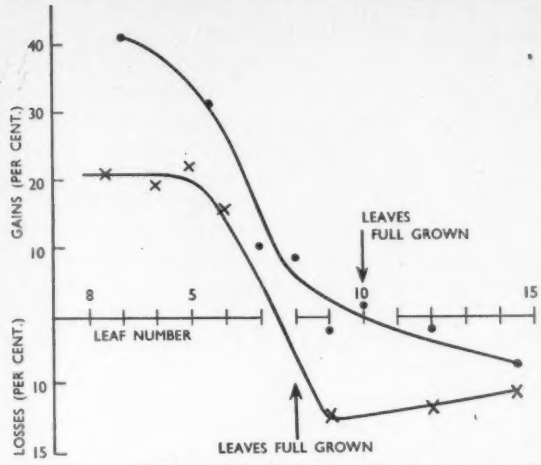


FIGURE 3 – *Gains and losses of protein nitrogen as per cent. of that originally present (after floating on sugar nitrate solutions for three days) in leaves of different ages numbered from the shoot apex downwards. Garden nasturtium* (Tropaeolum majus) (•) *and broad bean* (Vicia faba) (X)

medium. Generally speaking, then, we may say that there is a gradual fall in percentage protein content during the life of a tissue, which is associated not only with the drift in the plant tissues from protein synthesis towards protein hydrolysis, but with a decline in the proportion of nitrogen-rich proteins, and with the replacement of protein formation by carbohydrate accumulation.

These slowly drifting physiological states in an organ such as a leaf are, however, often disturbed in the entire plant by the development elsewhere of actively growing tissues. When this happens, as for example in the development of wheat grains on the plants, hydrolysis of protein in the vegetative parts becomes pronounced, and, as figure 2 shows, most of the protein nitrogen is removed from the vegetative parts to the developing grains. It has been suggested that the balance between protein synthesis in different parts of a plant is determined by the intensity of growth in various places, so that the most actively growing parts behave as 'sinks' into which soluble forms of nitrogen are attracted. Undoubtedly this is not the complete truth. In the primary leaves of the runner bean (*Phaseolus*) at the time of the steady state, the development of the adjacent stem growing-point is associated in the primary leaves with marked increases in soluble nitrogen and a reduction of protein nitrogen. In the leaves, therefore, the balance between protein synthesis and protein hydrolysis is disturbed in the direction of hydrolysis. This type of change in wheat leaves is well illustrated in figure 2, where increases in the soluble nitrogen occur at the time of seed development. Presumably a chemical messenger or some other regulator is transmitted from the newly active growing-point to the vegetative tissue, there to increase the rate of hydrolysis.

It seems also that the steady state in a leaf is disturbed by removing the leaf from the plant,

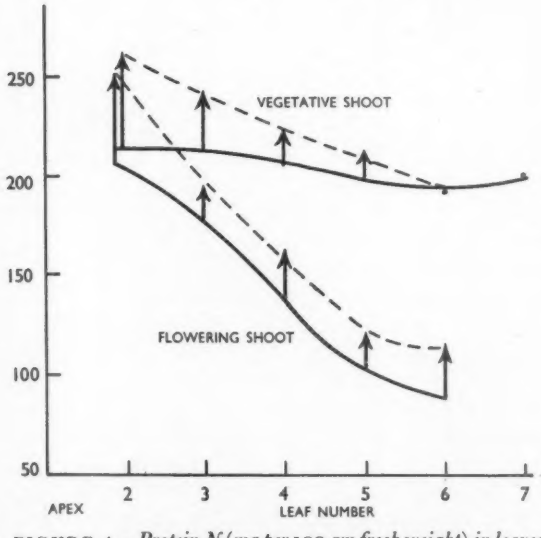


FIGURE 4 – *Protein N (mg per 100 gm fresh weight) in leaves of* Coleus sp. *during vegetative and flowering phases (continuous lines), and increase in protein N in detached leaves floating on sugar nitrate solutions (amount shown by arrows).*

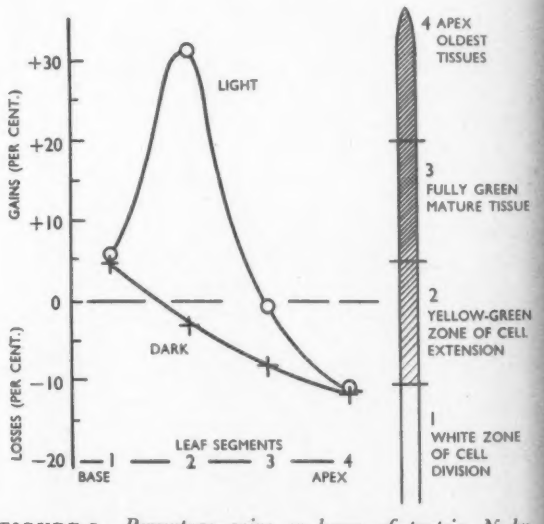


FIGURE 5 – *Percentage gains or losses of protein N by daffodil leaf segments after 72 hours in light* (○) *and in darkness* (+) *on sugar-nitrate solutions. The method of dividing leaves is shown on the right.*

for then also there becomes evident a strong tendency towards protein hydrolysis. It is accordingly interesting to determine the conditions under which synthesis of protein can be induced in such isolated tissues. It was shown long ago by Zaleski that a certain amount of protein synthesis resulted when detached leaves were floated on solutions containing nitrate and suitable sugars. Such experiments show clearly that the presence of abundant carbohydrate supplies is necessary for protein synthesis in such a case. From what we have already seen as to the change from growing synthetic tissues to senescent tissues, it should be clear also that the age of the detached leaf is a very important factor in deciding to what extent it can synthesize protein or not. By floating leaves of various ages and sizes on sugar solutions (3 per cent. glucose with 0·2 per cent. ammonium nitrate present) it can be shown that detached leaves from a plant such as the garden nasturtium (*Tropaeolum majus*) are not capable of increasing the net protein content under these experimental conditions after they have reached their full length (figure 3). It is probable that when leaves are attached to the plant they may continue to manufacture protein for a somewhat longer time. Figure 1, for Swiss Chard, shows that overall increase in protein nitrogen can be observed to continue after the increase in leaf length has ceased, and, on our hypothesis of the circulation of material through the cell proteins, it seems that synthesis must continue, and must equal protein breakdown, for a much longer time than is suggested by experiments on detached leaves.

Thus, even in detached leaves, protein synthesis is not always impossible in older specimens. When a plant starts to flower it is often the case, and perhaps invariably so, that the protein nitrogen content of the leaf falls to a very low level. When leaves from flowering shoots of *Coleus* were in this condition of low protein content it was found that they were able to synthesize protein when floated on sugar solution with nitrate present, even although vegetative leaves of corresponding age had lost the capacity to do so. In such an example the flowering shoots had a protein content of only about one-half that of the normal shoots (figure 4) and it looks as though the drain on the protein content had been so great that the leaves had regained the ability to reconstitute the transported material.

In some cases the leaf cannot so easily be used as an age-unit as it is in the above examples. A typical monocotyledonous leaf like that of daffodil (*Narcissus*) consists of tissues of very different ages and potentialities. The tip is the oldest part, and at the base there remains for a long time a white meristematic tissue which continues to grow and to produce new leaf material. To some extent this growing region imposes a barrier between the older parts of the leaf and the rest of the plant, and it is only when the whole leaf is old and showing marked signs of degeneration at its tip that migration of materials from the leaf to the rest of the plant is easily possible. The protein content of monocotyledonous leaves thus continues to increase for a very much longer period than is usual in a typical dicotyledon. The distribution of protein synthesis in such a leaf is therefore complicated by the growth organization of the tissues as a whole. Leaves like those of the daffodil (figure 5), however, are very suitable for investigation, because the leaf can be divided into segments of different ages, starting from the white growing tissue at the base (1) and passing through successive stages. Next come the yellow-green extending tissues (2) just above the base; the middle of the leaf is mature (3) and no longer growing; and the tip is old (4) and may even show signs of senescence.

The overall drifts in the nitrogen content of these different regions are shown in table I, which also shows the drift in nitrogen content of the entire leaves in relation to flower development. The influence of flowering upon the removal of protein is very evident, particularly of course in the apical segments. The data in the last column show that the average protein content of the leaves remains high for a considerable time—actually about twenty days, for the intervals between the four samples were ten days each.

Leaf segments like those of daffodil are a convenient material for studying other aspects of nitrogen metabolism, particularly some of the effects of light. When parallel samples of leaf segments are kept in darkness and in light, floating upon sugar-nitrate solutions, it is possible to show that there are very striking differences in the extent to which the protein synthesis is affected in different parts of the leaf. A typical set of results is summarized in figure 5. This shows that light has no apparent effect upon protein synthesis in the white growing parts of these leaves, but a very great one in the young extending portions, in which there is so large an acceleration of protein synthesis as to cause considerable net gain of protein. These tissues still retain some of their capacity for growth (like the white basal segments), but they also contain a light-absorbing mechanism, the green chlorophyll pigments, and

TABLE I

Protein nitrogen content of leaf segments of daffodil leaves (Narcissus pseudo-narcissus) *as mg per* 10 *gm fresh leaf.*

Stage of development	*Nitrogen content:*				
	of segments				*of whole leaf*
	1 (*base*)	2	3	4 (*tip*)	
(*a*) Young (three-quarter grown) ..	28	37	57	76	51
(*b*) Mature (non-flowering)	27	36	58	74	50
(*c*) Mature (flower buds half grown) ..	28	37	55	67	50
(*d*) Old (flowers in bloom)	24	33	50	52[1]	40

[1] Tips showing beginnings of yellowing.

it is evidently the energy so absorbed that leads to increased protein synthesis. Under the experimental conditions employed, however, the effects of light are insufficient to cause net protein synthesis in mature leaf segments, although light prevents hydrolysis. In the aged tips of the leaves, light does not prevent protein hydrolysis even in the isolated leaf segments.

It is possible in this type of experiment to construct detailed balance-sheets of the materials present in the tissues and in the external solutions. By this method of accounting it can be shown that in the green tissues, as contrasted with the white basal parts, light accelerates both the rate of absorption of nitrate from the external medium and also the rate at which it is utilized (i.e. converted to other things) in the tissues. By making certain assumptions as to what is happening in such tissues, provisional estimates of the rate of formation of organic nitrogenous substances in light and in darkness have been made, which suggest that light accelerates the formation of these substances in green tissues (Pearsall and Billimoria, 1939).

Essentially similar results have been obtained with the green unicellular alga *Chlorella*, growing on a sugar-nitrate medium. In this case it is possible to show that cell-division or protein synthesis (both being equivalent) is so affected by light at 23° C as to give a doubling of the initial cell number or protein weight in fourteen hours instead of in twenty-four. A comparatively small light intensity (100 millimetre candles) will produce this effect during the 'unlimited' or exponential phase of growth in which protein synthesis is most rapid, and little further effect at this stage is obtained by increasing the light intensity.

Analysis of this example, and of the last one (*Narcissus*), suggests that light is effective in two ways—first by increasing the permeability of the protoplasm so that metabolic processes in general go on more rapidly, while substances are absorbed more readily from the external solution. Secondly, however, there must also be a direct effect of light energy, which is used directly in the processes leading up to protein synthesis, as well as in producing sugars which are indirectly effective in giving the carbon chains required for amino-acid formation. This direct effect of light energy seems to act at two stages in the sequence of events leading to protein formation: the stage when nitrate is reduced to ammonia (or its *in vivo* equivalent), and the stage when the substance formed is combined with a carbon chain to give amino-acid or its equivalent.

Very interesting evidence of this direct effect of light on nitrogen metabolism has been obtained by Burström (1943) as the result of studies on wheat plants. He used for experiments wheat leaves previously grown in such a manner that they contained adequate supplies of nitrate. The samples of detached leaves were then illuminated in a stream of air containing the normal concentration of carbon dioxide. Three estimates were made in each experiment: (*a*) the amount of sugars formed in the leaves, (*b*) the amount of nitrate disappearing in the course of the experiment, (*c*) the amount of carbon dioxide absorbed. Burström claims, on the earlier evidence of Nurmia, that during carbon dioxide assimilation, for periods up to twenty-four hours, no carbohydrates other than soluble sugars are formed in the wheat leaves. As he found that the amount of carbon dioxide assimilated in his experiments was considerably in excess of the sugars appearing in the tissues, he was led to assume that the excess of assimilated material not accounted for represented the nitrogenous compounds formed from the combination of products of nitrate assimilation and of carbon dioxide assimilation. A typical set of results is given in table II, which shows how the other assimilates rise as the assimilated nitrate increases and also as the light intensity is raised.

Another point made by Burström is that there seems to be a definite quantitative relationship between the amount of assimilated nitrate and the carbon dioxide assimilation linked with it. The curves illustrating the assimilation of nitrate and the formation of other assimilates follow each

TABLE II

Influence of light on the assimilation during twenty-four hours of carbon dioxide and nitrate, with normal carbon dioxide content of the air. Carbon dioxide and assimilates computed as hexoses. All data as millimols per gm fresh weight of lamina. (*After Burström.*)

Light intensity (lux)	*Increase within the plant of:*			
	CO_2 *assimilated* (*a*)	*sugars* (*b*)	*other assimilates* (*a–b*)	*nitrate assimilated*
0 ..	−0·042	−0·038	−0·004	−0·001
2,900 ..	0·004	0·010	0·014	0·007
8,800 ..	0·057	0·012	0·045	0·019
18,000 ..	0·174	0·098	0·076	0·031
30,000 ..	0·303	0·098	0·127	0·040

other closely, and indicate that, for each molecule of nitrogen reduced, about fourteen molecules of carbon dioxide are combined with it into materials of a non-sugar nature. Now, of course, there is no protein which has a molecular relation of C : N in any way resembling this value of 14. The only common plant material which has a C : N relation of this sort is the green pigment chlorophyll (C : N = 13·6). As a general rule, the C : N ratio of protein is close to 3·9, so that, assuming that Burström's interpretations are correct, there must be formed, in addition to protein, some other carbon-rich substance. If the tissues were growing, this might be cell-wall material, e.g. cellulose, which would not appear in the carbohydrate analyses. There is, however, another possibility, which is that the plants form organic acids in addition to protein during the assimilation of nitrate. In the experiments with *Narcissus* already mentioned, it was found that light produced little or no alteration in internal sugar concentration as compared with darkness. This indeed might be expected, since the leaf segments were floating upon sugar solution and both the illuminated and the darkened segments took in much sugar. In contrast, however, there were marked changes in acid content, though this was measured only as the titratable acidity. The acidity was much higher when the leaf segments were illuminated, a condition in which they also converted much more nitrate. The extra acid production was roughly in proportion to the larger nitrate assimilation.

More definite evidence of a connection between nitrate assimilation and acid production has since been obtained from another species of *Narcissus* (*N. poeticus*), and also from tobacco and *Bryophyllum* plants, by Vickery and Pucher (1940) and their associates. They have examined the effects on these plants of supplying them during growth with nitrates, rather than with ammonium salts, as a source of nitrogen. They find that one well-marked metabolic effect of this treatment is that larger quantities of organic acids appear in the tissues. Particularly prominent are the increases in malic acid and isomers of citric acid, in addition to other acids as yet unidentified. We thus have to suppose that nitrate assimilation is linked to organic acid production in such a way that each unit of nitrogen assimilated leads to an increase in the amount of carbon compounds entering the organic acid pool. It may be pointed out that this increase must be considerable, although the data do not enable a quantitative estimate of the magnitude to be made. It must allow not only for the increased acid content of the tissues, but evidently also for those carbon chains necessary to build up amino-acids from the products of nitrate assimilation. Thus, if Burström's figure of 14C : 1N be accepted, and if about four carbon atoms on an average might represent the proportion of carbon chains required for protein, the remaining ten carbon atoms would be those going to other metabolic products, such as organic acids and cell-wall materials.

Even in its earlier stages, then, nitrogen assimilation serves to link widely different aspects of metabolism. The evidence here surveyed suggests that we shall ultimately find that a knowledge of the physiology of protein synthesis and degradation will provide an important means of integrating many phenomena of plant metabolism.

BIBLIOGRAPHY

Alsopp, A. *Nature*, 161, 833, 1948.

Burström, H. *Ann. Agric. Coll. Sweden*, 11, 1, 1943.

Dent, C. E., Stepka, W., and Steward, F. C. *Nature*, 160, 682, 1947.

Gregory, F. G., and Sen, P. K. *Ann. Bot.* (N.S.), 1, 521, 1937.

McCalla, A. G. *Canadian J. Res.*, 9, 542, 1933.

Pearsall, W. H. *J. Exper. Biol.*, 8, 279, 1931.

Pearsall, W. H., and Billimoria, M. C. *Ann. Bot.*, 3, 601, 1939 (N.S.).

Pearsall, W. H., and Loose, L. *Proc. Roy. Soc.*, B, 121, 451, 1937.

Pucher, G. W., Vickery, H. B., *et al. Plant Physiol.*, 22, 205, 1947.

Richards, F. J. *Ann. Bot.*, 2, 491, 1938 (N.S.).

Steward, F. C., and Street, H. E. *Ann. Rev. Biochem.*, 16, 471, 1947.

Vickery, H. B., and Pucher, G. W. *Ann. Rev. Biochem.*, 9, 529, 1940.

The Lister Institute of Preventive Medicine

HARRIETTE CHICK

Early in 1889, the Lord Mayor of London, Sir James Whitehead, went to Paris to consult Pasteur about the control of rabies. He returned with the determination to establish a treatment centre for rabies in London. In spite of opposition he drove on with his project, and the British Institute of Preventive Medicine was founded in 1891. Dr Chick tells the story of the institute (now the Lister Institute) and describes some of its manifold activities.

Although the Lister Institute under its present name and organization has been actively engaged for over forty years in research in medical and allied sciences, its activities have in reality been spread over more than fifty years. As the British Institute of Preventive Medicine, it owed its origin in 1891 to the energies of a committee formed after a Mansion House meeting held two years earlier to discuss the urgent problem of the control of hydrophobia in Great Britain. The successful treatment of the disease at the Pasteur Institute in Paris, where over 200 of our fellow-countrymen had been treated gratuitously, was made the basis of an appeal for funds to discharge this debt, and as a result a sum of about £2,000 was sent to Pasteur as a contribution to his recently opened institute. At the same time the committee, recognizing the seriousness of the lack of any institute in this country having aims similar to those of the French or other Continental institutes, launched a further appeal for funds to remedy this national defect.

Financial support was forthcoming from several City Companies and other sources, and the British Institute of Preventive Medicine, which had been amalgamated with the then existing College of State Medicine, became possessed of a capital sum of about £50,000 and of premises in Great Russell Street, London. Here the work of the new institute was started. By the beginning of the present century, however, changes had taken place in its name, its system of management, and its places of work. The Lister Institute of Preventive Medicine became established in buildings on a fine site on the Chelsea Embankment which had been purchased under very generous terms from the then Duke of Westminster. Lord Lister, first chairman of the governing body, held the office until ill health compelled his resignation in 1904, after which date he became the president of the institute; he was succeeded as chairman by Sir Henry Roscoe. The latter was in turn succeeded by Sir John Bradford, Sir David Bruce, Professor William Bulloch, and, in 1942, by Sir Henry Dale.

While the energies of the staff and other workers in the Chelsea buildings were mainly devoted to fundamental research in medical science, an important part of the work of the institute was connected with the experimental farm for the study and production of diphtheria antitoxin and other therapeutic sera. In the first instance, in the absence of special accommodation, horses for this purpose were housed at the Brown Institution in London through the co-operation of Dr (later Sir Charles) Sherrington, who was then the professor superintendent. There, in August 1894, the first diphtheria antitoxin to be produced in this country was obtained by Dr M. Armand Ruffer (at that time Director of the Institute), and by Sherrington. In the same year this branch of the institute's work was transferred to premises at Sudbury, Middlesex, and in 1903 to more suitable quarters in open country at Elstree, Hertfordshire.

ORGANIZATION OF THE SCIENTIFIC ACTIVITIES OF THE INSTITUTE

The appointment of Dr (later Sir Charles) Martin, F.R.S., in 1903 as director was followed by expansion of the institute's activities in many directions.

The number and character of the different departments of the institute has been kept fluid and elastic. Against a permanent background formed by the main departments of bacteriology, experimental pathology, and biochemistry, other smaller divisions have from time to time arisen, flourished, and in turn diminished. These have usually been formed in response to need for special

FIGURE 1 – *The laboratories of the Lister Institute at Chelsea, London.*

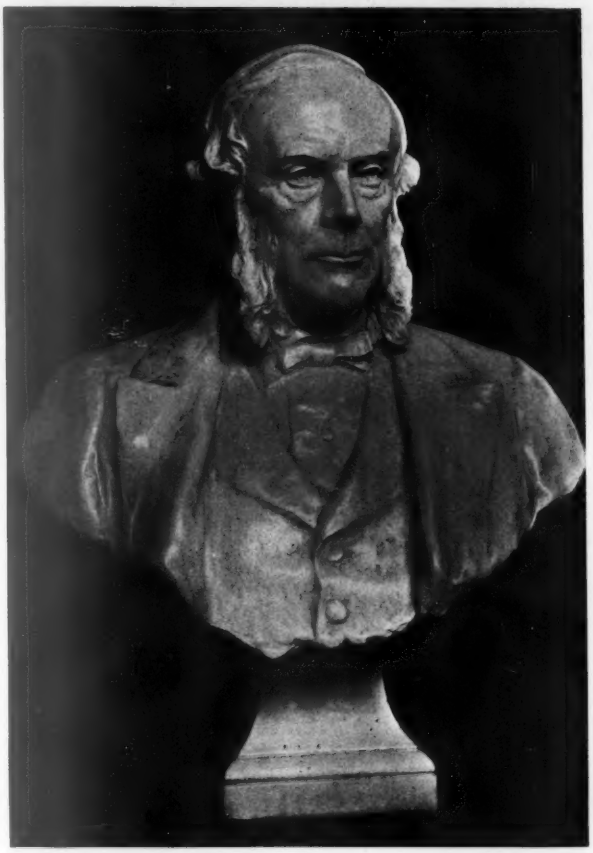


FIGURE 2 – *Lord Lister. Original plaster cast from a bust by Sir Thomas Brock.* (*National Portrait Gallery.*)

FIGURE 3 – *Sir Arthur Harden in his laboratory at Chelsea*, 1929.

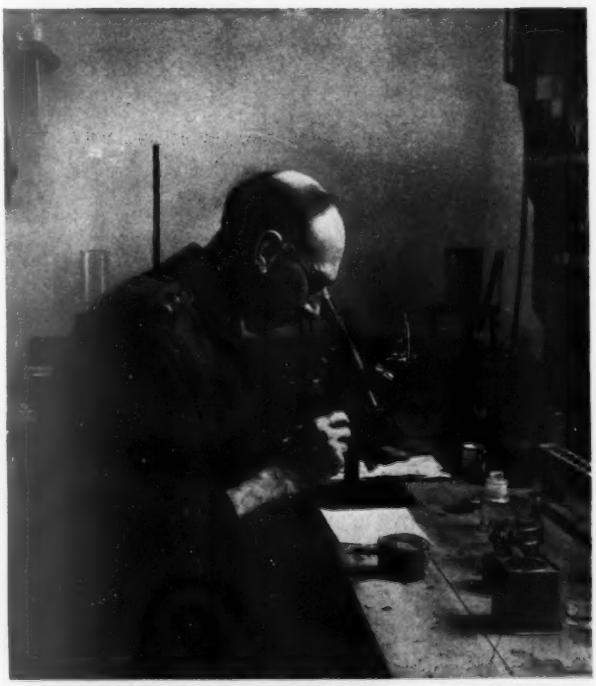


FIGURE 4 – *Sir Charles* (*then Lt.-Col.*) *Martin in his laboratory in Cairo*, 1916.

FIGURE 5 – *The laboratories of the Lister Institute at Elstree, Hertfordshire. On the left are the buildings for the preparation of vaccine lymph and bacterial vaccines; those in the centre are for the preparation of antisera. The stables and farm buildings are seen on the right.*

FIGURE 6 – *Blood being taken, with aseptic precautions, from the external jugular vein of an immunised horse. The preparation of antitoxin is an important part of the institute's work.*

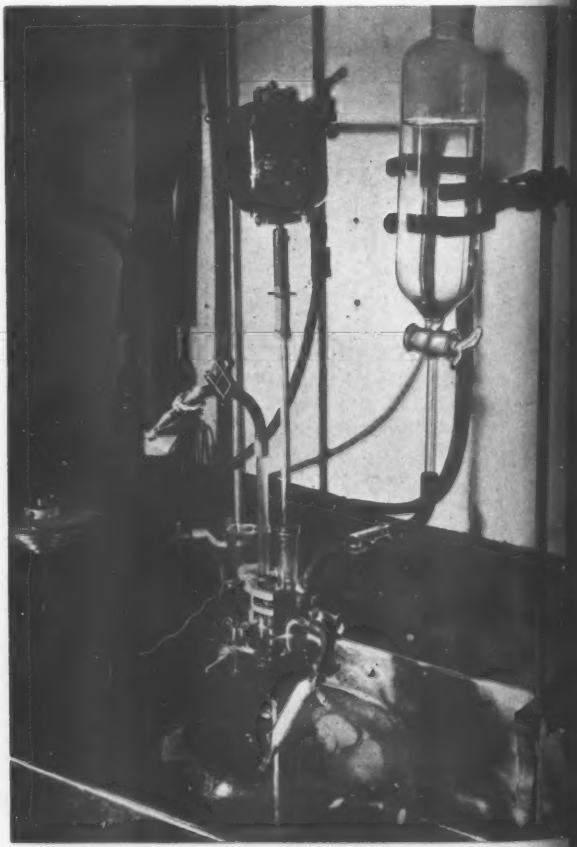


FIGURE 7 – *Apparatus for the aseptic precipitation by ether of gamma globulin from human serum.*

tation by

research of a topical character, and sometimes to provide scope for the special gifts of individual members of the staff. Among such have been the departments of protozoology, entomology, and statistics. The study of accessory food factors, begun in 1911 and extended during the years of the 1914–18 war in response to wartime needs, led to the formation in due course of a Division of Nutrition. The National Collection of Type Cultures was founded in 1920 by the Medical Research Council and housed since that date in the Lister Institute. It developed from a relatively small set of authentic tested cultures of pathogenic organisms used for teaching, research, and the preparation of the diagnostic sera which were distributed to the pathological services of British forces during the 1914–18 war. The most recently formed unit, that of biophysics, originated from the gift in 1935 of an ultracentrifuge by the Rockefeller Foundation.

It has been the custom to maintain a relatively small scientific staff which, together with the holders of the various research fellowships and scholarships included in the establishment, has never exceeded about thirty in number. The hospitality of the institute and its resources have, however, always been made available to suitably qualified guests who may wish to carry out investigations in the fields covered by the institute's activities. The number of such attached workers, including British investigators and others from the Commonwealth and from foreign countries, has at times nearly equalled that of the established staff. In particular, many members of the external scientific staff of the Medical Research Council, as well as workers holding temporary grants or research fellowships from that body, have been accommodated, and one or more holders of Beit Memorial research fellowships have usually been found among the attached workers at the institute.

SOME OUTSTANDING RESEARCHES

SPREAD OF PLAGUE

The institute took an active part in the elaborate series of investigations on the spread of plague organized in 1905–8 by the committee for the investigation of plague in India, on which body the institute was represented in addition to the Royal Society and the India Office. In 1905 the director, Dr Martin, with two members of the staff, went to India to work in the Parel Laboratory, Bombay, where, in collaboration with members of the Indian Medical Service, an elaborate series of experiments was planned and carried out with the aim of determining the mechanism by which bubonic plague is spread among rats and conveyed to human subjects. These researches, which were continued over three years, succeeded in establishing as the carrier of the plague bacillus, the rat flea, *Xenopsylla cheopis*, which usually infests the wild rat (*Mus rattus*) in tropical and subtropical regions of the world.

CAISSON DISEASE AND THE DANGERS OF DEEP-SEA DIVING

Work on this subject was rendered possible by the gift in 1906 from Dr Ludwig Mond of a large steel pressure chamber fitted with a double-action compressor pump for circulating air at different pressures. The chamber was large enough to accommodate two persons comfortably, and was used for trials on men and animals with compressed and rarefied air. Studies could thus be made upon physiological adaptation to raised and lowered atmospheric pressures, such as are experienced in deep-sea diving and caisson operations.

ALCOHOLIC FERMENTATION

The researches of Dr (afterwards Sir Arthur) Harden and his pupils on the alcoholic fermentation of sugar by yeast are some of the most famous which have emanated from the institute, and have proved to be of unexpected general scientific importance. In this work, the first important achievement was the discovery that yeast juice could transform sugar into alcohol only in the presence of another substance acting as a co-enzyme or co-ferment. This could be separated from the zymase ferment of yeast by passage through a gelatin filter. Neither alone could ferment sugar, but when they were mixed fermentation proceeded at a normal rate. The chemical constitution of the co-ferment, or co-enzyme as it is usually called, was later investigated with success by Professor v. Euler of Stockholm, with whom Sir Arthur shared the Nobel prize for chemistry in 1929. A second fundamental discovery was the fact that before any breakdown of the sugar molecules occurred combination with phosphoric acid was necessary, and that only after this preliminary phosphorylation had been achieved did they become susceptible to disruption by the enzymes in yeast zymase.

These discoveries of Harden and his colleagues, showing the importance of phosphorylation, have provided the clue to the elucidation of many biological phenomena involving the action of enzymes. For example, the mechanism of the

production of lactic acid in metabolism of carbohydrates by the enzymes of muscle has shown an astonishing similarity to that of yeast enzymes in the alcoholic fermentation of sugar.

Further work on carbohydrate-phosphoric esters, carried on by Professor R. Robison, led to the discovery of the hexosemonophosphate which commonly bears his name. Phosphoric esters were found to be concerned in the deposition of calcium phosphate during the ossification of cartilage in growing animals, and thus to play an important part in the formation of bone.

OTHER BIOCHEMICAL RESEARCHES

Since 1940, and following the death of Professor Robison, the activities of the biochemical department have been largely concerned with the isolation and characterization of the substances responsible for the group-specificity of human red blood corpuscles. A knowledge of the physical, chemical, and immunological properties of these substances is essential for a thorough understanding of the scientific basis on which the modern technique of blood transfusion rests. Dr Morgan and his colleagues have succeeded in isolating these specific factors, and have investigated their most important immuno-chemical properties. It is now established that the A, B, and the so-called O specific substances are mucoids, that is, polysaccharide-aminoacid complexes, which possess extremely labile structures. These closely related gene products are very similar chemically, although each possesses its own specific immunological characters.

Studies in the department since 1942 have also included in the role of the toxins of *Clostridium welchii* in gas gangrene infections, and the chemical nature of the bacteriostatic substances gramicidin, gramicidin S, and tyrocidine.

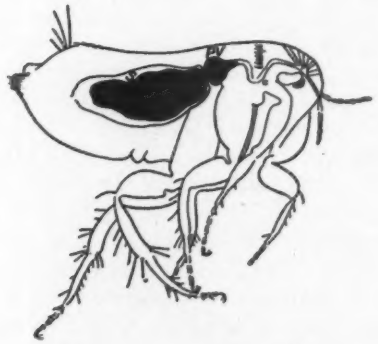


FIGURE 8 – *At the beginning of this century the Lister Institute played an important part in the elucidation of the mechanism of transmission of bubonic plague. This drawing of a plague-infected rat-flea with proventriculus (PV) and stomach (S) blocked with culture of plague bacilli is taken from Bacot and Martin, J. Hyg.* 13, 423, 1914.

BACTERIOLOGICAL INVESTIGATIONS

In the earlier decades of the present century the department of bacteriology was the largest and probably the most active in the institute. Chief among the workers was Dr (later Sir John) Ledingham, F.R.S., who became bacteriologist-in-chief in 1909 and was director of the institute from 1931 to 1943. His work on trench fever, on its minute causal 'rickettsia' forms, and on the technique developed in its study, was a preliminary to important work on the viruses of vaccinia and fowlpox. There is now no doubt that the so-called 'elementary bodies' which could be demonstrated under a high-power microscope represent at least one stage in the life of these viruses. Proof was forthcoming in the results of later work, which showed the specific antigenic action possessed by preparations of these elementary bodies when injected into horses. Other infective viruses which were made the subject of study were those of vaccinia and foot-and-mouth disease.

BACTERIAL VARIATION

Bacterial variation is a subject which engaged the attention of members of the bacteriological staff for many years, particularly of Sir Joseph Arkwright, Sir John Ledingham, and Dr Penfold. The discovery that alteration in the shape of the colonies of many pathogenic bacteria was associated with alteration in virulence and immunizing value was an impetus to these studies and has afforded valuable results.

ROLE OF VITAMINS IN NUTRITION AND ETIOLOGY OF NUTRITIONAL DEFICIENCY DISEASES

As early as 1911 and the years following, Dr Casimir Funk was engaged in the department of biochemistry in an attempt to separate from yeast the substance, to which he gave the name of 'vitamin,' which would prevent tropical beriberi in man, and in birds the polyneuritis already recognized as an analogous disease. At the same time in the department of experimental pathology a study was made of the distribution of this vitamin in common foodstuffs, and of the influence of the amount of carbohydrate in the diet upon its requirement.

During the first world war, occurrence of beriberi and scurvy among our armies abroad created

a further urgency for the study of these nutrition diseases. Temporary helpers were secured to assist the greatly diminished institute staff, and researches were undertaken upon the properties and distribution in foodstuffs of the anti-beriberi vitamin, now known as vitamin B_1 (aneurin or thiamin), and of the anti-scorbutic vitamin, now known as vitamin C or ascorbic acid.

The prevalence of rickets among children of the countries of central Europe following the privations of the 1914–18 war focused attention upon this disease and upon the unsolved problem of its etiology. Reports from Vienna in 1919 also described a condition of osteomalacia, seen in the poorer elderly population, which was thought to be analogous to that of rickets in children. In the autumn of 1919 Vienna was visited by a small unit of workers, supported jointly by the Lister Institute and by the Medical Research Council, which continued to work in that city for about three years. With the friendly co-operation of Professor Clemens v. Pirquet and his staff at the university *Kinderklinik* an elaborate series of investigations was made upon the etiology of rickets. The results of these trials showed that the disease in infants could be prevented or cured with certainty, either by administration of preformed Vitamin D in cod liver oil or other foods, or by exposure to natural sunshine or to ultra-violet irradiation from artificial sources, and that the physiological action of these three agents was indistinguishable. Hunger osteomalacia in adults and late rickets in adolescents were found to react in a similar manner.

RESEARCHES ON HUMAN BLOOD-PLASMA

By special methods involving the use of ether, the active fractions of blood-plasma—the gamma globulin, the thrombin, and the fibrinogen—can be isolated. The fibrinogen when mixed with thrombin forms a solid clot, and is used in surgery to surround and secure a sutured nerve. By special treatment a sponge-like preparation of 'fibrin-foam' is produced. This, if moistened with thrombin and placed on an area of bleeding, causes the blood to form a solid clot in the sponge, which can be left in position and, being a natural substance, is slowly absorbed by the body and is a form of dressing of special use in brain surgery. The gamma globulin, the fraction which contains the natural antibodies against certain diseases, has been used successfully for prevention of measles or mitigation of its severity. The staff of the unit of biophysics is concerned in the preparation of these materials, and an extensive series of drying plants has been constructed in which they can be dried from the frozen state and supplied in the dry form. In addition, special refrigerated rooms have been erected and methods of preparing human plasma for transfusion purposes have been developed.

NATIONAL SERVICE IN THE TWO WORLD WARS

The nature of the contribution made to national service has differed somewhat in the two world wars. In the years 1914–18 almost the entire staff, both scientific and subordinate, was occupied in service abroad in the pathological and hygienic services of the Royal Army Medical Corps. Only a small remnant, consisting largely of women, remained to cope with the routine and research work of the institute, which assumed a definitely topical character in response to the national needs. In the second world war this island was itself in the front line of the conflict and the staff of the Institute was occupied to a greater extent with national service at home. The vulnerable position of the buildings at Chelsea, which suffered one direct hit during the London air raids in addition to damage from blast on more than one occasion, necessitated the evacuation of several departments to more peaceful surroundings where suitable hospitality was offered and accepted. In such often improvised accommodation research work was continued; investigations of more fundamental nature were laid aside for the time being and others of more direct application to national war-time needs were adopted as far as possible. Among these may be mentioned the investigations on the differing nutritive value of flours derived from different portions of the wheat grain, undertaken to provide information which might guide the authorities in selecting the most economical and nutritious flour for bread-making under war conditions, and the studies of the stability of vitamins in foods under conditions of storage. Considerable progress was also made in the preparation of protective and curative vaccines against typhoid fever and of curative sera for gas gangrene.

Under the guidance of the present Director, Dr A. N. Drury, F.R.S., appointed in 1943, the institute has undergone a considerable degree of reconstruction necessitated by the changed conditions obtaining at the end of the war. Its activities in the future will doubtless differ from those of the past, as befits a research institution where change and development are symptomatic of healthy life and progress.

Decay of timber by fungi

W. P. K. FINDLAY

The role of fungi in causing decay in timber has been recognized for about a century, and much work has been done on the elaboration of methods of wood-preservation. A problem of first importance was the recognition of wood-rotting fungi in the absence of their fructifications: this has been largely solved by making comprehensive culture collections. Dr Findlay shows that modern knowledge renders unnecessary the waste of much good timber.

HISTORICAL IMPORTANCE

When the warships that defended the shores of Great Britain were built entirely of wood, the prevention of rot in their hulls was a matter of supreme importance to the nation. From the time of Charles II, right up to the coming of the ironclads in the middle of the nineteenth century, there are numerous records of the loss and damage to warships caused by rot. Samuel Pepys, the famous diarist who was also Clerk to the Admiralty Commission, reported that ships had been 'suffered to heat and moulder till I have with my own hands gather'd toadstools growing in the most considerable of them, as big as my fists.'

The problem reached its height during the Napoleonic wars, when large numbers of vessels were built of unseasoned timber; great men-of-war, containing 3,000 loads of timber, became useless in two to three years. At the conclusion of hostilities, half the ships in the Navy were said to have been in a rotten state; some were found to have rotted even before they were launched. The subject was frequently raised in Parliament and became a matter of public concern and alarm. Although the role of fungi in causing decay of timber was, as yet, by no means clearly understood, James Sowerby, the eminent botanist, in a report to the Commissioners of the Navy in 1812, described and named the fungi which he found, thus clearly associating the decay of the wood with the presence of the fungi. He was well aware of the importance of providing proper ventilation to prevent accumulation of moisture (see figure 9).

The term 'dry rot' was first used about 1775, to describe the fungal decay which eventually reduces wood to a dry-looking mass that crumbles to powder at a touch. It is in many ways an unfortunate appellation for a trouble that invariably develops under damp conditions, and the term has frequently led to misunderstandings; it has, however, become so well established in the English language that it cannot be altered. Its use should be restricted, however, to the decay of timber in buildings, brought about by certain specialized fungi. Dry rot of timber in buildings does not appear to have become serious until towards the end of the eighteenth century, when soft woods began to replace the much more durable oak for building purposes, and there are many references to dry rot in woodwork of famous buildings about this period. Prizes were offered by the Royal Society of Arts, London, for a cure for dry rot, and many strange specifications and remedies were proposed in articles published in the early nineteenth century.

An important practical advance in the art of preserving wood against decay was made by Bethell, who patented, in 1838, the process of impregnating wood with an antiseptic under pressure—a process subsequently developed and improved by Boulton, whose patent is dated 1879. Although the practical application of this method of preserving wood, by impregnating it with creosote under pressure, was soon taken up on a large scale in this country, little attention to the subject of wood rot was given by scientific men until Marshall Ward began his studies at Coopers Hill in 1890–1900.

To Robert Hartig, in Germany, must be given the credit of first establishing that fungi are the cause of decay in wood, and his work was followed by other scientists in Germany, a country in which forestry and timber problems have for a long time received serious attention.

Pioneer work in the United States of America was undertaken at the beginning of the present century by von Schrenk, and since then the work of the Forest Products Laboratory at Madison in Wisconsin, and other research institutes, has contributed a great deal to our knowledge of wood-rotting fungi.

In the past Great Britain has not been to any

noteworthy extent a timber-producing country, and little research on the diseases of trees or of timber was undertaken until after the first world war. The establishment in 1927 of the Forest Products Research Laboratory at Princes Risborough, having as its objective the better utilization of timber, provided a centre for research on wood-rotting fungi and the preservation of wood.

RECOGNITION OF CAUSES OF DECAY

One of the first problems to be tackled was the development of means of recognizing wood-rotting fungi in the absence of their fructifications. Only a few fungi produce a rot which is sufficiently distinctive to allow the causal fungus to be identified with certainty. Microscopic examination of the hyphae, and of their effects on the cells of the wood, seldom yields any more definite information than that a wood-rotting fungus is at work. It was found, however, that the appearance of the fungi, when grown in pure culture on a standard medium, is often sufficiently characteristic to permit the species to be recognized, either by its texture or colour (see figures 1 and 2), or by the presence of certain microscopic features. Physiological characteristics, such as the rate of growth at various temperatures, reaction to varying degrees of acidity in the medium, etc., can also be helpful in determining the identity of a fungus in culture. In order to become familiar with the characteristics of these fungi in culture it is necessary to have at hand cultures prepared from named fructifications, and a comprehensive collection of such cultures must be available in any laboratory undertaking research in timber pathology. The practical value of being able to identify the cause of decay in any sample of wood is that, once identification of the causal fungus is established, the source and origin of the infection can usually be determined. For instance, if the fungus found responsible for decay in imported rock elm timber of a boat can be identified as a species that occurs in standing elm trees in Canada, it can be concluded with a fair degree of certainty that the wood was infected before shipment, and indeed came from a diseased tree.

It is difficult to describe cultures with sufficient precision to enable another worker to recognize them, but recently attempts have been made to prepare comprehensive keys for the identification of fungi from their appearance in culture on agar media. Figures 1 and 2 illustrate cultures that are sufficiently characteristic to be readily recognized from their general appearance.

EFFECTS OF DECAY ON PROPERTIES OF WOOD

Wood-rotting fungi secrete enzymes that can bring about profound changes in the physical properties and chemical compositions of timber. While it is a matter of common knowledge that rotten wood is soft, it is only recently that accurate tests have been made to discover how far the various strength-properties of wood are affected at different stages of attack by various kinds of wood-rotting fungi.

During the war, when supplies of high-grade timber for aircraft were scarce, it became a matter of importance to determine the influence of various defects and blemishes on the mechanical properties of these woods, so that no unnecessary rejection of timber should be made. It was found that plywood made from veneers containing slight incipient decay might have strength-properties but little inferior to those of plywood made from perfect veneers, and good use was thus made of material that would otherwise have been scrapped.

The property which is most rapidly affected by incipient decay is the toughness or resistance to impact or shock. For instance, in one experiment the toughness of samples of ash (*Fraxinus*) exposed to the fungus *Polyporus hispidus* fell by 20 per cent. after two weeks' exposure to attack, and was reduced by 75 per cent. after only eight weeks. Bending strength was also affected immediately, but depreciated only by 30 per cent. after 28 weeks' exposure. This immediate effect on toughness is probably due to breakage in the linkages between the chains of cellulose molecules, brought about by the hydrolysis caused by the fungal enzymes.

The density of wood falls as fungal decay proceeds, and, in the case of fungi that can attack all its constituents, wood can be utterly consumed. On a study of their chemical action, the fungi that attack wood can be divided into two classes:

1. Those which produce hydrolysing enzymes and attack the cellulose and associated pentosans, bringing about *brown* carbonizing rots which leave the wood in a friable, powdery condition (see figure 3).
2. Those which produce oxidizing as well as hydrolysing enzymes, attack all the constituents of the wood, including the lignin, and bring about *white* or light-coloured rots (see figures 4 and 5).

It is easy to test cultures of wood fungi for the presence of oxidases by the addition to the culture fluid of a substance such as guaiacum, and this reaction is a useful diagnostic feature as to the type of rot a fungus can produce.

NATURAL DURABILITY OF WOOD

Timbers vary greatly in their resistance to fungal decay. Some, like beech and poplar, perish rapidly if left in contact with the ground; others, like teak and ironbark, may last for centuries. There has been a good deal of speculation as to the reason why one timber is more durable than another. Attempts have been made to correlate the durability of timbers with their densities, but this correlation does not hold, for there are some lightweight woods (such as western red cedar) which are very resistant to decay, and some fairly heavy woods which are readily decayed. Reasons for differences in natural resistance have therefore had to be sought in the chemical make-up of the wood. The basic wood substance appears to vary comparatively little from one species to another within the groups of the broad-leaved and coniferous trees, so it is among the minor constituents, such as the water- or alcohol-soluble extractives, that one must seek the natural preservatives which confer resistance on the wood. Recent work in Sweden has shown that it is the presence of small amounts of a highly toxic phenolic compound called pinosylvin which renders the heartwood of Scots pine so much more resistant than the sapwood, while the similar material in western red cedar has been isolated and named thujaplicin. Cartwright has shown that the resistance to decay may vary in different parts of the trunk of a single tree of western red cedar, being lower at the centre of the heartwood than in the outer layers, and that this variation can be correlated with the amount of water-soluble material present.

Laboratory tests have been devised by which the natural resistance to decay of a wood can be determined much more rapidly than in field exposure trials. Many unfamiliar timbers from Africa and South America are now coming on the markets of western Europe to replace well-known species that are scarce, and it is essential to find out as much about their properties as possible, so that they can be put to the best use with the minimum delay.

PRESERVATION OF WOOD BY CHEMICALS

For a hundred years or so, creosote distilled from coal tar has been the standard material for the preservation of timber, and for many purposes no better preservative has been, or is likely to be, found. It has, however, certain disadvantages, such as its effect on paint. In parts of the world remote from industrial areas where tar distillation is carried on, the cost of transport may make creosote expensive, and in these circumstances it is more economical to use a water-soluble material which can be transported in solid form and made up with water on the spot. Until recently, most water-soluble preservatives suffered from the disadvantage that they were leached out of the treated wood by the action of rain, but it has been found that, by the addition of chromates, toxic chemicals such as copper and arsenic can be fixed and rendered less soluble after they have penetrated into the wood, and several effective water-soluble preservatives of this type are now on the British market. A recent development has been the use of substances toxic to fungi which are soluble in oils but insoluble in water, so that the toxin is deposited in an insoluble form after evaporation of the solvent. Pentachlorophenol and copper naphthenate are two compounds now used extensively for the preservation of wood in this way.

The length of time that is required to test wood preservatives by field or service tests has led to the development of rapid laboratory methods for their evaluation, and a British Standard method for determining the toxicity to fungi of wood preservatives has been published.

PREVENTION OF DECAY OF TIMBER IN SERVICE

In spite of the advances in knowledge about the physiology of wood-rotting fungi and about means of preventing damage by them, an immense amount of wood is, in the aggregate, allowed to decay prematurely even in highly developed countries. Few countries still possess a superabundance of timber, and none can afford to waste this precious raw material, for which there is an unsatisfied world demand. The cost of effective impregnation with preservatives has not risen to the same extent as the cost of timber (which in Great Britain is three to four times its pre-war figure), and therefore the saving that can be effected by preservative treatment shows a marked increase over the pre-war level.

In Europe, repair and maintenance work on all types of buildings, especially dwelling-houses, was neglected for five years or more, and dry rot is exceedingly prevalent; it is no exaggeration to say that millions of pounds sterling have been spent since the war on repairing the ravages of dry rot in England alone (see figure 13). Dry rot has been particularly prevalent in buildings where fires, caused by incendiary bombs, were extinguished with large volumes of water. Much of the damage

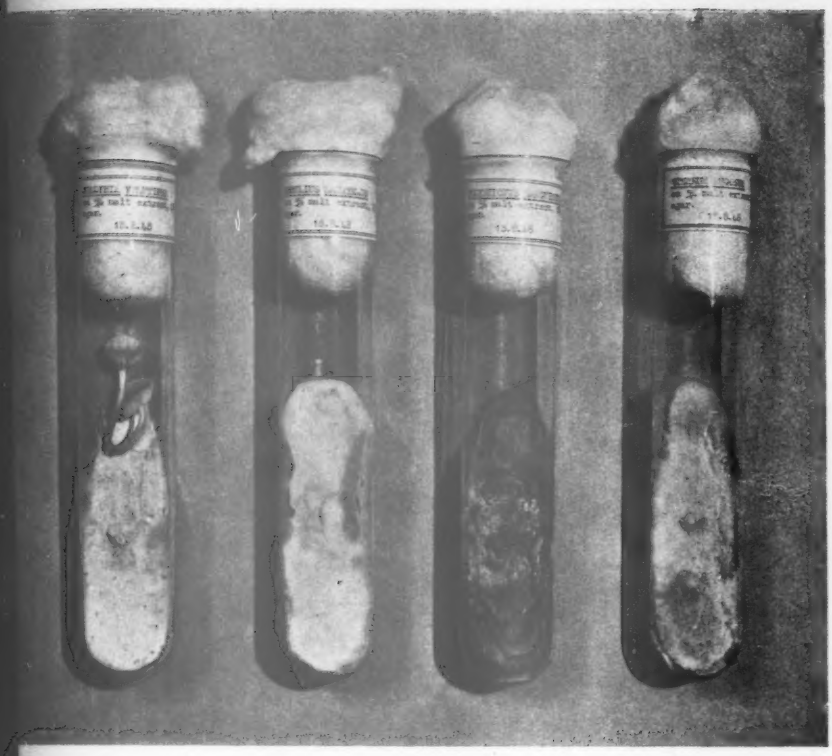
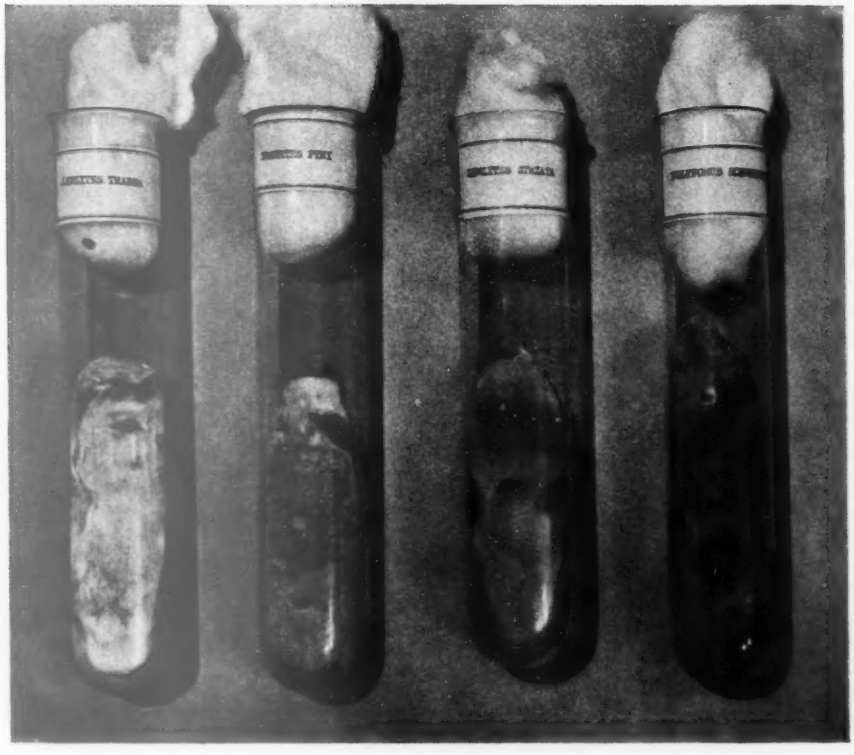


FIGURE 1 – *Cultures on* 5 *per cent. malt agar of wood-rotting fungi. Some of these possess a characteristic texture or coloration by which they can be readily recognized.*

From left to right: Collybia velutipes (*with fructifications*), Merulius lacrimans, Polystictus sanguineus, *and* Stereum rugosum.



URE 2 – *Cultures on* 5 *per cent. agar of (from left to right):* zites trabea, Trametes pini, zites striata, Polyporus schwei-ii.

FIGURE 3 – *Brown pocket rot in opepe* (Sarcocephalus diderrichii).

FIGURE 4 – *White rot with pronounced zone lines in birch.*

FIGURE 5 – *White pocket rot caused by* Trametes pini *in imported Douglas fir.*

FIGURE 6 – *Sap stain* ('*blue*' *stain*) *in sapwood of pine, caused by* Ceratostomella *sp.*

FIGURE 7 – *Brown oak. The warm brown coloration is caused by the beefsteak fungus,* Fistulina hepatica. *This kind of oak is often used for furniture of high quality.*

FIGURE 8 – *'Green oak': the colour is due to the fungus* Chlorosplenium aeruginosum. *This wood has been used for decorative inlaid work.*

FIGURE 9 – *One of the earliest illustrations of the dry-rot fungus,* Merulius lacrimans (*plate* 113 *of Vol.* 1 *of Sowerby's* Coloured Figures of English Fungi or Mushrooms, 1797). *Sowerby describes the fungus as 'much too common in England . . . as the fructification is seldom without drops of water resembling tears the Latin name* lachrymans *or weeping has been given'; and concludes '. . . the best way to guard against this evil is to introduce a free circulation of fresh air and avoid building in damp situations.'*

FIGURE 10 – *Growth of* Poria vaillantii *mycelium on decaying pit props in a coal mine.*

FIGURE 11 – *Sporophores of* Polystictus versicolor *on sapwood of oak log. Note absence of fungal growth on the heartwood.*

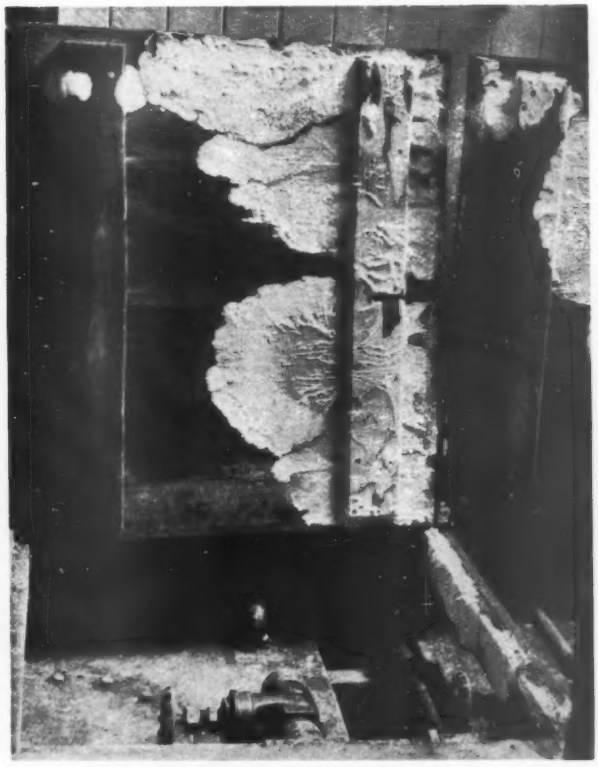


FIGURE 12 – *Fungal growth on wood floor above water tanks in motor launch.*

Figures 10–12 are reproduced by permission of the Director of Forest Products Laboratory. (Photographs Crown Copyright reserved.)

FIGURE 13 – *An exceptionally vigorous growth of dry rot fungus* (Merulius lacrimans) *on shelving in basement cupboard that had been shut up for years. (By permission of G. W. Walford & Partners.)*

could have been prevented had the conditions that lead to dry rot been more widely understood by the general public, and had simple precautions been taken to dry out buildings into which leakage of water had occurred. Architects and builders are now becoming increasingly aware of the need to prevent moisture reaching woodwork and setting up conditions favourable for dry rot, and plans for the new types of houses—both of prefabricated and of traditional types—are scrutinized from this point of view. The use of timber impregnated under pressure with wood preservatives is also steadily increasing. It is therefore most unlikely that the buildings now being erected will suffer from dry rot to the same extent as those built during the past century.

In many mines, decay of the pitwood has in the past been rapid and the cause of increased charges (see figure 10). The Transvaal Chamber of Mines, convinced that substantial saving can be effected by proper preservative treatment of timber used in the gold mines of the Rand, has established a special timber research laboratory. An interesting sidelight on the value of timber preservation in these mines was the discovery that the fungus responsible for a serious skin disease of the mine-workers—sporotrichosis—could be controlled by preservative treatment of the pit-props, which not only prevented the growth of wood-rotting fungi but also inhibited the development of the pathogenic mould that causes the skin disease.

During the war, large numbers of wooden vessels were built, and experience with certain types has shown the need for preservative treatment of any woodwork that cannot be adequately ventilated. Many private yachts were laid up for years and suffered much deterioration from decay that would not have occurred had the appropriate preservative treatment been applied to the vulnerable parts (see figure 12).

The story of the campaign for the proper packing and preservation of stores destined for the tropical theatres of war, the so-called 'tropicalization,' has been told elsewhere, but we are still finding evidence of the need to 'preserve' packing cases for stores that have to be kept for lengthy periods in the open, or in damp or ill-ventilated stores, such as underground mine workings or quarries.

PREVENTION OF DECAY IN LOGS

Less timber than formerly is now available from the Baltic countries and Russia, and the countries of western Europe are looking to the forests of Africa and South America to supply the deficiencies. In former times, the bulk of the timber from tropical countries consisted of such species as teak, mahogany, greenheart, and other durable or relatively durable species, which could be shipped without serious risk of deterioration between the time they were felled and the moment when they were sawn up in this country. Today there is also a demand for the softer, light-coloured woods from these countries—the so-called 'soft hardwoods'; but many of these species are attacked very quickly after felling by wood-boring insects, and by fungi that cause either disfiguring stains or decay. Practical methods for preventing this deterioration are being studied in West Africa, and some measure of successful control has already been obtained in experiments with logs sprayed with emulsions of pentachlorophenol and benzene hexachloride.

NEED FOR EDUCATION AND DEVELOPMENT WORK

In most countries, forestry has been the poor relation of agriculture, and forest utilization problems have seldom received the concentrated study that has been given to agricultural problems of a similar nature. Yet the adequate scientific and technical information now available could enormously raise the standard of timber utilization, and prevent by far the greater part of the needlessly rapid deterioration that all too often takes place. It is not implied that there is no need for further research on the pathology and preservation of timber—on the contrary, there is an urgent need for extended work in this field, especially under tropical conditions, where termites are responsible for at least as much damage as fungal decay—but with the knowledge and methods already available a very great deal more can and should be done to reduce needless waste of good timber through premature decay.

Flight at supersonic speeds

S. G. HOOKER

Flight at speeds greater than that of sound presents many problems to the aircraft designer and engineer. Dr Hooker explains that, for the designer, one of the most serious difficulties is that an aircraft built to fly at supersonic speeds at high altitudes becomes unmanageable at low altitudes and at the much lower speeds necessary for landing and taking off. For the engineer, the major problem is the provision of a compact power unit capable of generating the great power necessary to overcome the high drag experienced at these speeds.

Announcements in the United States press have told us that a number of American pilots have now flown, in level flight at high altitudes, a special rocket-propelled aircraft at speeds greater than the velocity of sound; more recently a British pilot, Mr. John Derry, has exceeded a Mach number[1] of unity in a dive, flying the De Havilland 'Swallow' jet-propelled aircraft.

The research work carried out by the Germans during the recent war in the field of supersonic flight, impressive in its quantity, quality, and breadth of vision, adds to the signs and portents of our time that a new era in flight is approaching —the supersonic era. Britain is not likely to lag behind in these developments.

Until 1940 the speed of aircraft had been limited to about 400 m.p.h., or 0·55 Mach number, and no appreciable advance on these figures seemed probable or possible with the conventional type of power plant consisting of an airscrew and reciprocating engine.

THE JET ENGINE

The advent of the jet engine, however, completely changed the picture. Here was a new power plant—light, compact, enormously powerful, and, moreover, possessing the very desirable property of propulsive efficiency increasing with forward speed. In a few years the world's speed record has risen from 55 per cent. of the speed of sound to more than 85 per cent., and high Mach number effects in the airflow about the wings and body have passed from the realm of mathematical curiosities to become dangerous realities.

What are these peculiar conditions that arise as we approach and exceed the velocity of sound? How do they affect our conception of the supersonic aeroplane of the future? Concerning these questions much remains to be learned from research, and more from the practical application of known results to the design of aircraft, but the broad lines upon which the progress in design must develop are already fairly firmly established.

Let us consider the peculiar circumstances arising when a body travels through the air at speeds greater than the velocity of sound. By definition, the velocity of sound is the speed at which small pressure disturbances caused by a body will be propagated in all directions, and it is these pressure disturbances which make the presence of the body felt in the surrounding atmosphere. Evidently, if the speed of the body is greater than that of sound, then the air ahead of the body will be completely 'unaware' of its approach. In the upper diagram of figure 1 let A_1, A_2, A_3, A_4 be successive positions of the body travelling in the direction indicated with speed U greater than sound. Then, while the body moves from A_1 to A_4, the disturbance caused by its nose will have travelled at the speed of sound to all points on the circle of radius A_1P_1; and similarly during the interval between A_2 and A_4 a circle of disturbance of radius A_2P_2 will be formed. Evidently the complete disturbance caused by the nose of the body will be confined between the lines A_4B_1 and A_4B_2, which thus constitute waves making angles of $\sin^{-1}(a/U)$ to the direction of motion. These limiting waves are the envelope of all disturbances originating from the nose of the body in its passage in the direction indicated, and they are propagated normal to themselves at the speed of sound. The air external to the angle formed by A_4B_1 and A_4B_2 is completely unaffected by the approach of the body.

Extending the above argument to a wing, as in the lower diagram of figure 1, every point on the wing surface will propagate a sound wave inclined at an angle $\sin^{-1}(a/U)$ to the direction of motion, and the picture of the disturbance caused by the

[1] By Mach number (M) we mean the ratio of the speed of the aircraft to the velocity of sound.

JU

D
SI
SI

w
th
in
tr
ti
w
sp
ph
w
as
ve

d

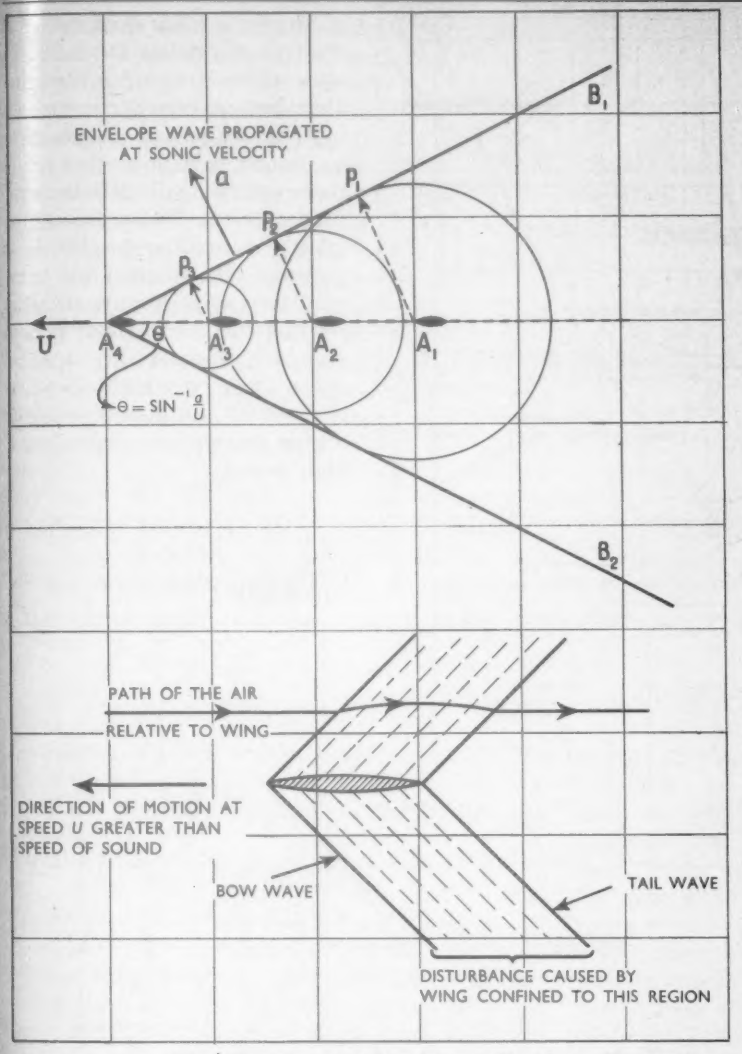


FIGURE 1 – *Wave formation set up by wing travelling faster than sound.*

wing will be as indicated. It is confined solely to the region between the bow and tail waves, and, in fact, the wing disturbance is attached to, and travels along with, the wing itself—in contradistinction to conditions below the speed of sound, where the disturbance precedes the wing and spreads to all regions of the surrounding atmosphere at the speed of sound. The fact that the wing is continuously generating this wave system as it travels on its course is responsible for the very large drag which is experienced.

DESIGN AT SUPERSONIC SPEEDS

The diagrams in figure 2 show the changes in design which may be expected as we reach and exceed the speed of sound. Firstly, in regard to the wing, or aerofoil, section. At speeds up to $M = 0{\cdot}7$ we have the conventional section designed to produce high lifts, having the upper surface more highly cambered than the lower. As we approach the speed of sound, the section should get thinner and tend to become symmetrical, having its maximum thickness at about half the chord. Finally, the supersonic section will be symmetrical, and will have sharp leading and trailing edges.

As a result of these changes, the drag coefficient will change as indicated. Up to about $M = 0{\cdot}8$ the coefficient will be unaffected by Mach number, and will stay at its low-speed value. Between $M = 0{\cdot}8$ and $M = 1{\cdot}0$ a rapid rise in drag coefficient will occur—reaching, perhaps, a figure five times as great as the low-speed value—and finally, at supersonic speeds, a decrease will occur, to about twice the low-speed value, at velocities greater than twice that of sound.

The plan form of the wings will also undergo radical changes. As we approach $M = 1{\cdot}0$, wings will be swept back at angles up to 45°, because this has been found to delay the onset of wave formation on the wing surfaces. The chord of the wing will be increased and the span of the wing decreased, because wings of low aspect ratio have been found to be less susceptible to wave formation.

Finally, at supersonic speeds, the leading edge will be swept back at a greater angle, up to 75°, and the plan form will tend to become triangular. Such a change will evidently result in great structural advantages—features very welcome in helping to overcome the large aerodynamic forces involved at such high speeds. It is more than probable that the ordinary tail will disappear altogether.

It may well be asked why these changes are so long in coming about. The answer is not far to seek. Aircraft have, of necessity, to take off and land

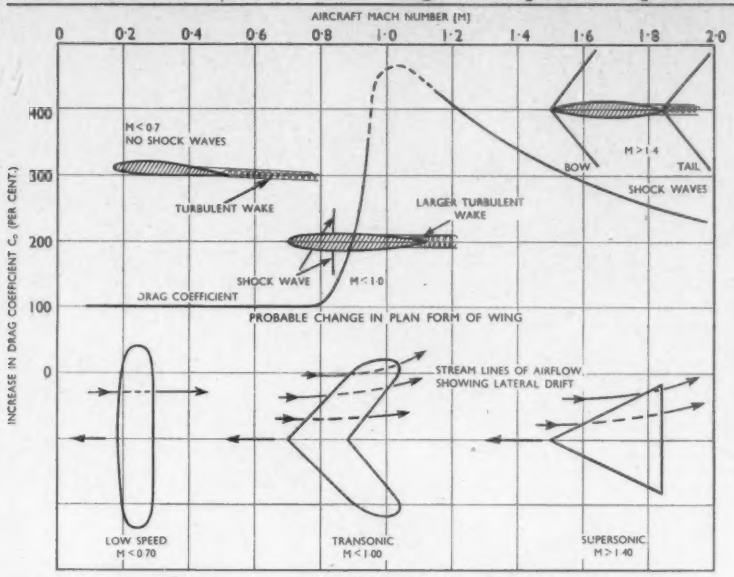


FIGURE 2 – *Changes necessary in design of wing as Mach number increases.*

at a moderate speed—say about 120 m.p.h., and while the changes indicated above are all advantageous at high speeds, they are almost as big a disadvantage under landing and take-off conditions. One of the most important difficulties is that the tips of the swept-back and triangular wings tend to stall first, thus causing a serious loss of control. The reason for this tip-stalling is that the airflow drifts outwards towards the wing tip owing to the inclined leading edge and, in fact, tends to slide off the wing tips laterally without producing any lift (see figure 2).

The take-off difficulty could, of course, be overcome by launching the supersonic aircraft from a 'mother' aircraft, as has been done in Britain in experiments using pilotless models. Alternatively, a rocket-propelled carrier on rails could be employed, similar to the system used by the Germans for launching the V1. Landing would be much more difficult, and parachutes might have to be used for the final descent.

No mention has been made of the type of fuselage for a supersonic aircraft, and this abominable but necessary excrescence must be reduced to an absolute minimum, so as to reduce resistance and not to disturb the aerodynamic flow. To keep the frontal area as small as possible, it is probable that the pilot and crew will have to lie prone. In this position the human body is best able to withstand the physical effects of the very high accelerations which are bound to occur during any manœuvring at these high speeds.

THE SO-CALLED SONIC BARRIER

The expression 'sonic barrier'

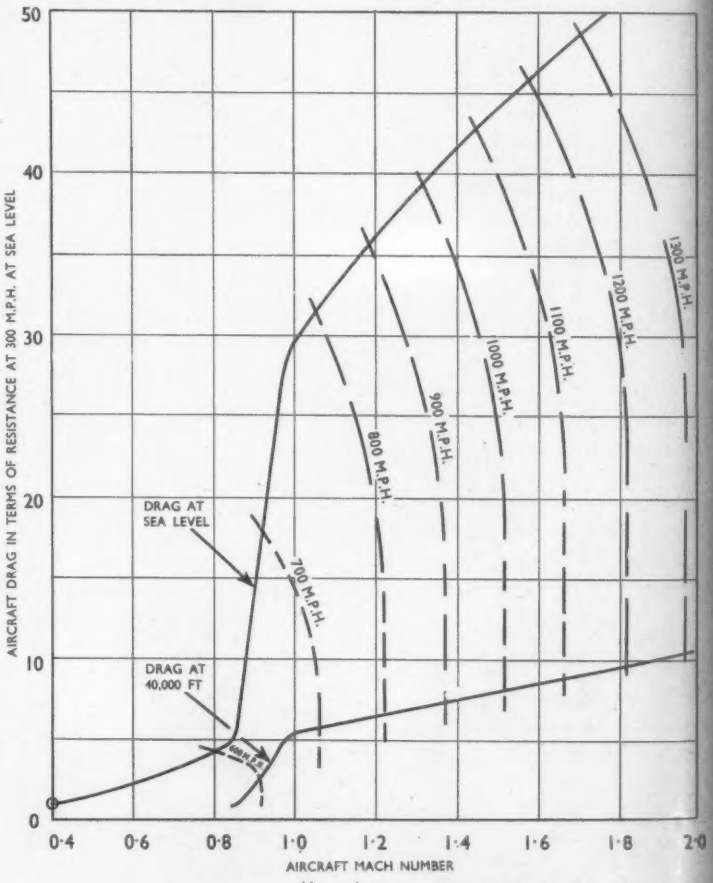


FIGURE 3 – *Air resistance at supersonic speeds.*

has become quite common, but we should not delude ourselves into thinking that there is a magic wall of air resistance occurring at the speed of sound, through which the aircraft must be forced, and that, once through, all will be plain sailing with no head wind. In fact, the air resistance increases continuously with speed, and the drag coefficient C_D shown in figure 2 must be multiplied by the air density ρ and the square of the aircraft speed V before the actual drag is obtained; thus:

$$D = \rho V^2 C_D$$

But the density of the air is proportional to its pressure p divided by its absolute temperature, and we can write:

$$D = p\frac{V^2}{T}C_D$$

Continuing, we know that the velocity of sound is dependent only upon the square root of the absolute air temperature, so that finally the drag is given by

$$D = KpM^2C_D,$$

where M is the Mach number of the aircraft.

Using the above equation and the form of C_D given in figure 2, we can construct the aircraft drag in terms of the resistance experienced at 300 m.p.h. (0·4 Mach number) at sea level. Note that the above equation shows that, at any given Mach number, the aircraft drag is proportional to the altitude pressure only. Figure 3 shows the calculated drag at sea level and at 40,000 ft. plotted against the aircraft Mach number.

Thus, at 1·8M at sea level the aircraft drag is 50 times as great as at 0·4M. To illustrate the point, a machine of the size of the Spitfire has a drag of about 1,000 lb at 300 m.p.h. at sea level. Doing our best with the aerodynamic form of the wing, an aircraft of this size would have a drag of 50,000 lb at 1·8M at sea level, and as this Mach number corresponds to 1,365 m.p.h. the thrust horse-power required would be no less than 182,000—rather more than it takes to propel the *Queen Elizabeth*! (Incidentally, the German V2 rocket developed a thrust of 60,000 lb within a diameter of 5½ ft.)

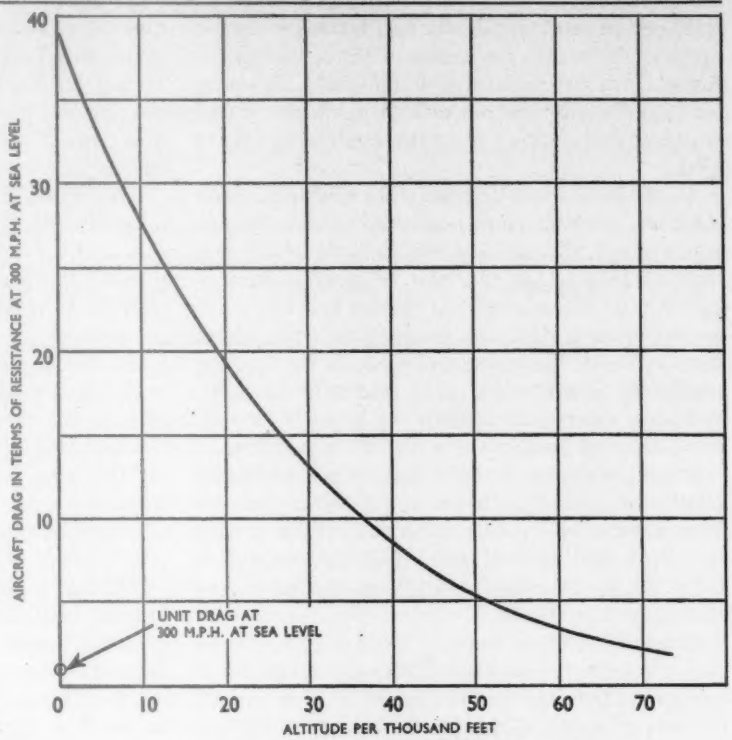


FIGURE 4 – *Drag on aircraft flying at* 1,000 *m.p.h.*

Assuming propulsion by a jet engine, the fuel consumption would be at the rate of 90,000 lb per hour. Evidently the horse-powers involved rule out completely the conventional airscrew and reciprocating engine.

Propulsion by rocket is even more expensive in fuel, the consumption being no less than 900,000 lb per hour for a thrust of 50,000 lb—ten times that of the jet engine.

Obviously supersonic flight at sea level will be possible for only a matter of seconds, owing to the high consumption of fuel, whatever type of engine is employed; and it is doubtful if enough fuel can be housed for the four consecutive runs (two in each direction) which have to be made over the measured kilometre at sea level in order to qualify for the world's speed record.

FLIGHT AT HIGH ALTITUDES

The picture changes if we go to higher altitudes into the region of thinner air. Figure 3 shows that at 40,000 ft, where the air pressure is only 5·54 cm of mercury, the drag at 1·8M has fallen to 9·5 times the drag at 300 m.p.h. at sea level; that is, to the more manageable figure of 9,500 lb. This would require a consumption of rocket fuel of only

50 lb per sec, and, in fact, the fuel housed in the V2 (18,000 lb) would be sufficient for a six-minute flight. This same quantity of fuel would, however, last a jet engine for more than an hour—a fact which is encouraging from the practical point of view.

To fix ideas more definitely, let us forget Mach numbers and consider an aeroplane travelling at 1,000 m.p.h. Figure 4 shows its drag at all altitudes, where again the unit of drag is that at 300 m.p.h. at sea level. At 70,000 and 60,000 ft we are getting down to drags of two and three times our unit (i.e. 2,000 and 3,000 lb for the case previously considered), and evidently at these altitudes supersonic aircraft with practical endurances and ranges are a distinct possibility.

It will, of course, be necessary to pressurize the pilot's cabin, and since the atmospheric pressure at 70,000 ft is only 33 mm an air compressor having a compression ratio of 16 : 1 will be required to bring the pressure in the cabin up to that corresponding to 10,000 ft.

Strangely enough, even at these high altitudes one of our major problems will be to keep the pilot cool. Owing to the forward speed, any air picked up and dragged along by the aircraft will be heated by 100° C. This is not due to friction, but is merely the energy which has to be given to the air in order to accelerate it from rest up to 1,000 m.p.h. The fuselage and wing surfaces might be expected to be heated by 85° C, and since at 70,000 ft the atmospheric temperature is −57° C, the temperature inside the cockpit would be at least 30° C or 86° F. Added to this, we have the heat due to the compression of the air by the cabin supercharger, and even with the maximum amount of cooling that we could apply to this air, the pilot would be uncomfortably hot and dry.

ENGINES FOR SUPERSONIC AIRCRAFT

What of the engine for supersonic aircraft? There appear to be three possible types: a rocket motor, a jet engine employing reheat in the jet pipe, and an aerothermodynamic duct or, more shortly, an athodyd.

As we have seen, the great disadvantage of the rocket is its huge consumption of fuel, which is primarily due to the fact that it has to carry its own oxygen along with it in the form of one of the fuels. In all other respects it has every advantage. It is light, mechanically—but not structurally—simple, and develops the same thrust at 70,000 ft as it does at sea level (again due to the fact that it carries its own oxygen).

The thrust of a jet engine, on the other hand, falls off almost proportionally to altitude air density, and is further limited by the maximum temperature which can be used in the combustion chambers, because of the decrease in physical strength of the turbine blades at high temperatures. Consequently, only about one quarter of the available oxygen can be used before reaching the turbine, but there is no reason why the remainder cannot be utilized in the jet pipe after leaving the turbine, thus increasing the thrust available. By this means 70–80 per cent. extra thrust can be obtained without endangering the life of the turbine blades.

Finally, there is the athodyd, which is the simplest of all engines. The fundamental cycle for any heat engine is first to compress the working fluid, then heat it, and finally to expand it, and this is in effect what the rocket or the jet engine does. Now, the forward speed of an aircraft is capable of compressing the air it picks up. If we mount a duct on a high-speed machine and give it a forward-facing intake, correctly shaped to diffuse the air velocity entering it into pressure, then we can burn fuel in the duct, and, having discharged it rearwards, we shall obtain a thrust which can be made capable of propelling the aircraft. For example, at 1,000 m.p.h. a compression ratio of 3·5 : 1 is theoretically obtainable in this way. In fact, the aeroplane acts as its own compressor, and all we have to do is to heat the compressed air with fuel and expand it through a rearward jet. Evidently this engine is inefficient at low speeds, where the air compression is small, and will give no thrust under static conditions. It is useless for taking the aeroplane off the ground, and does not come into its own until the machine is actually travelling at supersonic speeds. While it seems unsuitable as the main power plant, it may yet prove valuable as a booster unit once supersonic conditions have been obtained by other means.

The garden at Tresco

J. W. HUNKIN

The great garden at Tresco, in the Scilly Islands, deserves to be much better known. It is now over a century old, and although it was severely damaged by tempest in 1929 the recovery was very swift. Sir Arthur Hill, late Director of Kew Gardens, described the garden at Tresco as an imperial asset of great importance. The Bishop of Truro, in whose diocese the Scilly Islands lie, here gives an account of it, with coloured plates specially taken.

The Isles of Scilly consist of more than three hundred rocks and islets, situated about thirty miles west of Land's End. Five only are inhabited; of these St Mary's is the largest, and Tresco, about two miles to the north across a broad roadstead, is the second. The scenery is on a small scale, but there is a wonderful freshness in the air, and the colours of the white sand, the blue and sapphire sea, the golden seaweed, the sea pinks, and the gorse and heather, have the brightness of a jewel.

The modern history of the Isles of Scilly begins in the year 1834, when Mr Augustus Smith of Berkhamsted succeeded the Duke of Leeds as lessee of the islands from the Duchy of Cornwall. Augustus Smith fell in love with Scilly, and ruled there as lord proprietor—'Emperor of Scilly,' as his friend, Lady Sophia Tower, used to call him—until his death in 1872. It was a firm and benevolent rule, and the islanders, who had been in a very poor way in the early years of the nineteenth century, came to enjoy considerable prosperity.

Augustus Smith decided to live on Tresco. When he arrived, there was nothing growing on the island above the height of a gorse bush, save in the little parsonage garden, where there were a few small stunted trees. He chose a site for his house near the ruins of the ancient abbey, a small outpost of the Benedictine Abbey of Tavistock in Devonshire (figure 6), and began planting for shelter. He also built a sheltering wall and stocked his garden with interesting plants, many of them too tender to be grown in the open on the mainland. Some of these plants were sent to him from Kew, and others came from correspondents in Australia, New Zealand, and South Africa, or were grown from seeds brought home by his friends among the sea-captains. He gradually increased his shelter belts, using *Quercus ilex*, *Cupressus macrocarpa*, and *Pinus radiata*, and he took more of the hillside into his garden until it included some twelve acres on the southern slope of the central hill of the island.

The garden has three main walks: the 'Top Terrace' of some 300 yards, east to west, near the top of the garden; the 'Long Walk' parallel to it on the level ground at the bottom; and the 'Middle Terrace,' a third parallel between the other two, and rather shorter. There are various paths and steps connecting the three. The main way down is by the 'Neptune steps,' leading straight from an old statue of Neptune (figure 5) on the Top Terrace to the Long Walk below, a distance of about seventy-five yards, and on, a further seventy yards, to the old brazier of the lighthouse on another of the islands (St Agnes), now set up by the south wall of the Tresco garden. Near this south wall, a little farther west, is a veranda known as 'Valhalla,' because it contains some seventy old figureheads or other relics of ships wrecked on the islands (figure 3).

These wrecks are a tragic reminder that the great enemy at Scilly is the wind. The storms are sometimes very violent. In the winter of 1929–30, for example, there were no fewer than fourteen occasions when the wind rose to over eighty miles an hour. The temperature, however, is very equable and mild, seldom outside the limits of 40–60° F; and the hours of sunshine average nearly five hours daily. There are ten inches less rain in the year than at Penzance, on the mainland some forty miles away, the average at Tresco being 32·4. As for the soil, it is a light mixture of sand and peat which tends to become very dry in summer.

From the first, the Tresco garden was unlike any other in the British Isles. Augustus Smith made good use of the rocks and great stones of the island and made his garden brilliant with masses of mesembryanthemum, of which he had scores of varieties—his 'mesmerisms,' as he used to call them—with their thick succulent leaves and starry flowers, large and small, of glistening white, bright yellow, red, and purple. Two quotations from letters written to Lady Tower in 1858 give

vignettes of the garden, one in winter and the other in summer:

> *3rd January*, 1858. This gentle winter has not been unfelt in my garden, which is a blaze of blossoms wondrous to behold; the *Veronica Andersonii*, Correas, Fuchsias, Genistas, and above all *Acacia lophantha* are covered with flowers; one of the last particularly, not less than twelve feet high and as many broad, along the Long Walk, is a perfect picture; the Sedums also, with their large yellow pyramids of bloom, each nearly as big as my lamp papers, are very ornamental . . . and a certain set of *mesmerisms* are also in flower.
>
> *1st June*, 1858. My garden is a blaze of blossom, especially as to Geraniums; more than usual survived last winter, and whole beds of *Unique*, especially, and other sorts are one mass of flower; . . . The *Dracaena indivisa* is fast advancing to perfection; the flower is not very conspicuous, but a mass of white feathery stems crowning the summit of the plant; the blossom is white; . . .

In 1872 Augustus Smith was succeeded by his nephew Thomas Algernon Dorrien Smith, a lieutenant in the Tenth Hussars. In 1875 he married Edith, daughter of his uncle's great friend Lady Sophia Tower. They had seven children, and at Tresco they resided for eight months in each year.

It was Thomas Algernon who started in the islands the cultivation of the narcissus for the market, an industry which has proved to be the most remunerative of all the islands' industries. The 'Scilly White' and the 'Soleil d'Or' he found growing about the Abbey ruins. Possibly they had been introduced by the monks. As an experiment he persuaded Mr Trevellick, who held a farm on St Mary's, to send up some flowers to Covent Garden. He put them in a hatbox and realized a pound for them. The first flower show to be held in the Isles of Scilly took place on Tuesday, 30th March, 1886, when Thomas Algernon showed upwards of 160 varieties of narcissus, arranged on a groundwork of green moss.

Meanwhile he had been developing the abbey garden. He discovered that *Pinus radiata* (*insignis*) stood the wind better than *Cupressus macrocarpa*, and he was able to establish a belt of shelter on the south-west side of Tresco hill. The plants in the garden continued to flourish and grew larger and larger. Some which Augustus had never seen in flower came into blossom in the 'seventies and 'eighties. *Furcraea longaeva* was one of the most striking of them. From a yucca-like base it shoots up a very tall stem with slender branches bearing its cream cup-like flowers. The *C. macrocarpa* along the abbey drive formed itself into a huge hedge of beautiful and unusual green fifty feet high, which it took a fortnight every year to clip.

Thomas Algernon died in 1918, and the present owner, his eldest son, Major Arthur Dorrien Smith, D.S.O., succeeded him. The Major had already made his mark in the horticultural world, particularly by introducing from the Chatham Islands the finest of all the olearias, *O. semidentata*, with its great, lovely, purple, daisy-like flowers. He had travelled extensively in South Africa, Australia, and New Zealand, and had sent and brought to Tresco a large number of seeds and plants of various kinds.

Sir Arthur Hill, the late Director of Kew, wrote a short account of the garden in the *Kew Bulletin* (1920, No. 5), and after mentioning various species of acacia, melaleuca, hakea, *Leucodendron argenteum*, *Araucaria excelsa*, and the mesembryanthemums and pelargoniums of many colours and sizes flourishing as in their native homes, Sir Arthur concluded by describing the garden as 'an imperial asset of great importance to the botanists of this country whose work lies with the botanical resources of the British Empire.'

Some nine years later, in December 1929, the garden was devastated by a terrific tempest. On a Wednesday the gale was 93 miles an hour from the south-east, on the Friday above 110 miles an hour from the south-west, and on the Sunday 91 miles an hour from the north-west. The velocity of the wind did not fall below 70 miles an hour for more than eight hours during five days. Major and Mrs Dorrien Smith were away on the mainland at the time, and when they finally reached home in a torrent of rain they could hardly find their way. Paths were blocked and obliterated; trees, uprooted, had come crashing down on bushes and beds, and the ground was thickly strewn with branches and debris. Even the ilex had been stripped. Happily the recovery was far more rapid than one could have dared to hope.

In 1935 a beginning was made in compiling an official list of plants cultivated in the garden. Among the most interesting items are the following:

Acacia: 39 species.
Agave: 69 species, mostly from Mexico.
Aloe: 60 species.
Cistus: At least 15 species.

FI
OC

FIGURE 1 – Agave applanata, *with* Phoenix canariensis *in the background on the left.*

FIGURE 2 – *Prickly pear* (Opuntia occidentalis) *on the Middle Terrace.*

FIGURE 3 – *Ships' figureheads in 'Valhalla.'*

FIGURE 4 – *Lily pond on the Middle Terrace.* Watsó
Beatricis *in the foreground.*

FIGURE 5 – *Neptune steps lined by* Dasylirion acrotriche.

FIGURE 6 – *Polyanthus rose, veronica, and fuchsia,* o
arches of the ancient abbey.

Coprosma: 12 species, including *Baueri* with its handsome thick, shining leaves.
Cytisus: 21 species.
Echium: 7 species.
Eucalyptus: 29 species.
Fuchsia: 28 species, including *cordifolia, fulgens, splendens, triphylla*, and garden varieties.
Hedychium: 8 species, including *coronarium* and *Gardnerianum*.
Leptospermum: 11 species, including the Australian tea-tree (*L. laevigatum*).
Mesembryanthemum: 153 species.
Metrosideros: *diffusa, lucida, robusta, tomentosa*.
Olearia: 33 species.
Opuntia (prickly pear): 14 species.
Pelargonium: 159 species and distinct varieties, in charming groups all over the garden. Many have scented leaves.
Pittosporum: At least 18 species.
Rhododendron: 135 species including *Dalhousiae, Veitchianum, etc.*
Senecio: 34 species, including *grandifolius, Kirkii*, etc.
Veronica: 62 species.

There are also many cacti and succulents, bottle brushes, and Proteaceae.

For many years one of the great sights in the garden was the scarlet of the many fine trees of *Metrosideros tomentosa* blazing far out to sea in July. All these were badly scorched by the unusual frost at the beginning of 1947. When the frost came, in January, the garden was gay with the red spikes of many aloes. They were demolished at once. The great tender-looking clumps of *Sparmannia africana* were in full blossom, and their white flowers with golden stamens withered away too. Most of the Tresco plants, however, even when badly injured, were not absolutely killed. Perhaps the two most notable fatalities were the karaka and the puka, both from New Zealand, on the Long Walk. The immense lustrous green leaves of the latter will be greatly missed. On the whole, however, the recovery has been remarkable, and when I was in the garden early in June 1948 I was delighted to find it still its lovely and gracious self. Half a dozen puyas were holding aloft their enormous yellow-green spikes, the dracaenas had their heads full of flower with the effect of deliciously scented lace, and the clumps of mesembryanthemums dazzled the eye.

The coloured photographs give a good idea of the sub-tropical appearance of the garden. Figure 1 shows some of the great American agaves, and with them must be imagined the African aloes, the red spikes of which make the garden gay in January. In the background on the right of the picture is one of the magnificent Canary Island Palms, several of which were planted in 1908. Their giant fronds rise from a single main trunk which bristles with the remains of former fronds. In the crevices thus formed grow various self-sown little plants: *Veronica, Pittosporum*, and, strangest of all, *Metrosideros tomentosa*.

The dasylirions in figure 5 are stiff desert plants from Mexico, with narrow spiny-margined leaves. They withstood the frost of 1946–7 without damage, and in the succeeding summer a dasylirion in another part of the garden shot up its high spike of greenish flowers in an astonishing manner.

The *Watsonia Beatricis* in figure 4, with its rich apricot-red flowers, is one of a number of Watsonias in the garden. They are summer-blooming bulbs from South Africa, like aristocratic gladioli.

Fuchsias and veronicas of many bright colours (figure 6) are a great feature in the garden. A species of the latter with attractive blue and white flowers is called after the Major: *V. Dorrien-Smithii*. The shrubby New Zealand speedwells which are commonly included under the name *Veronica* are now to be called *Hebe*. The figure shows one of them: *Hebe Dorrien-Smithii*.

The generous hospitality of this unique botanic garden is still maintained by the public-spirited family who have developed and cared for it for over a hundred years. The notice composed by Mr Augustus Smith may still be read on a slab of slate just inside the gate at the end of the Abbey road:

> All islanders are welcome to walk in these gardens, but are requested to keep to the main walks, not to go up to the house nearer than the under terrace in front, and to abstain from picking flowers or fruit, scribbling nonsense, and committing suchlike small nuisances. Enter then, if it so please you, and welcome.

Science in the detection of crime

H. S. HOLDEN

Science is an important and often indispensable agent in the detection of crime. The methods and processes employed have nothing novel in themselves, and are already familiar to scientists in general. The interest of the subject lies in the particular applications to which science is directed, and in this article, by the detailed consideration of specific cases, Dr Holden (of the Metropolitan Police Laboratory at New Scotland Yard) shows how scientific investigation assisted in the solution of certain apparently insoluble criminal problems.

The employment in Britain of the specialized knowledge of the scientist in the detection of crime has, in the past, been relatively restricted except in certain well-defined types of case, although many of the methods characteristic of science—for example, accurate observation, the correlation of all available data, and reasonable inferences from such data—are commonplaces of all criminal investigation.

The type of scientific specialist first employed by investigating officers was, as might be anticipated, the expert in forensic medicine. His collaboration was essential in all cases coming under the general head of crimes against the person, such as crimes of violence and the whole range of sexual offences. Among the crimes in which the help of the medical expert was sought it was inevitable that there should be some in which poison was suspected to be the cause of death, and the analysis of the organs and body fluids necessary in such cases involved the co-operation of the toxicologist. The scientific study of poisons was first established on a sound basis just over a century ago, with the publication of Taylor's *Handbook of Poisons* in 1848; since that date progressive refinements in technique have been developed which enable the toxicologist to isolate, identify, and determine the total amount in the organs examined, even when the quantities are relatively minute. Toxicology is, of course, only one highly specialized branch of one particular science, and within the last twenty-five years police forces have come to realize that the services of scientific experts covering a much wider field may be utilized with advantage, not only in the types of crime which make headline news, but also in the relatively prosaic day-to-day offences such as housebreaking, larceny, forgery, road-traffic accidents, and the like.

The beginnings of this wider use of the scientist in British criminal investigation are to be traced to the institution of the small laboratories established by individual police forces in various parts of the country, notably at Derby, Bristol, Cardiff, and Nottingham. These laboratories did admirable pioneer work, employing the scientific staffs of local universities, university colleges, and technical institutes as consultants, but the areas they served were necessarily limited. It became increasingly clear that there was a real need for an extension of laboratory work of this kind to serve the country as a whole. Careful consideration of the steps necessary to provide such a national laboratory service was given by the Departmental Committee on Detective Work and Procedure appointed by the Home Secretary in 1935, under the chairmanship of Mr A. L. (now Sir Arthur) Dixon, C.B., C.B.E.

Largely as a result of the deliberations of this body a number of regional forensic science laboratories under Home Office control have been established, covering the whole of England and Wales. These laboratories are situated at Preston (North Western Region, including North Wales), Wakefield (North Eastern Region), Nottingham (East Midland Region), Birmingham (West Midland Region), Cardiff (South Wales Region, including Monmouthshire), and Bristol (South Western Region) respectively. The laboratory serving the Metropolitan Police District and south-east England is at New Scotland Yard, London.

The staffing and equipment of each laboratory are such as to enable it to deal with most of the material likely to be submitted by investigating officers. Provision is, however, made for obtaining the services of outside experts, notably those of skilled forensic pathologists, where the crime under investigation requires their collaboration. Close and friendly contact with the police forces of the region is maintained through the liaison officer, who is normally a detective officer of senior rank with a good scientific background and who can often advise his police colleagues on the collection

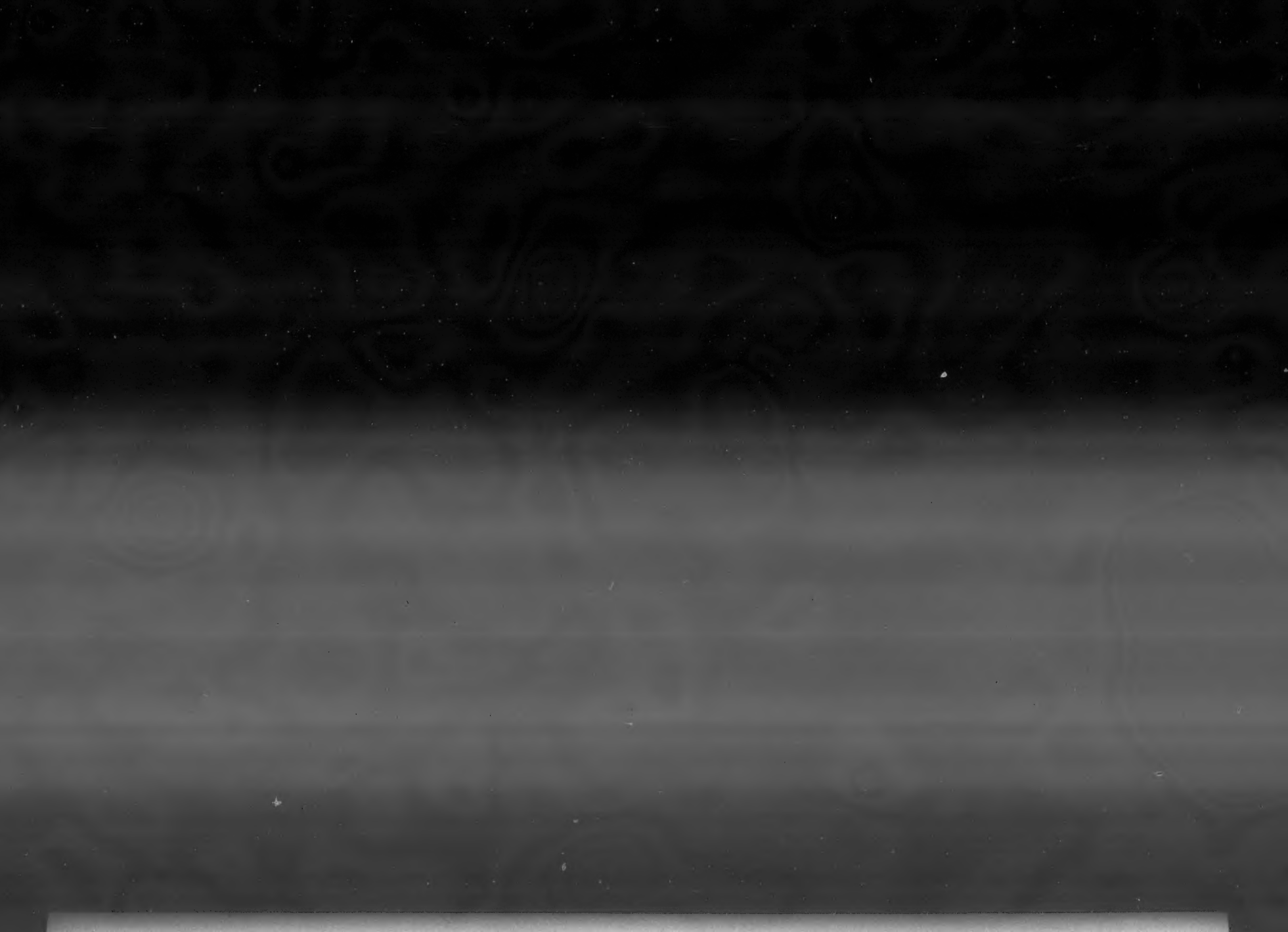


FIGURE 1 – *This car was suspected of being the cause of an accident in which a cyclist lost his life. The front nearside mudguard was damaged and a good deal of the paint had been lost.*

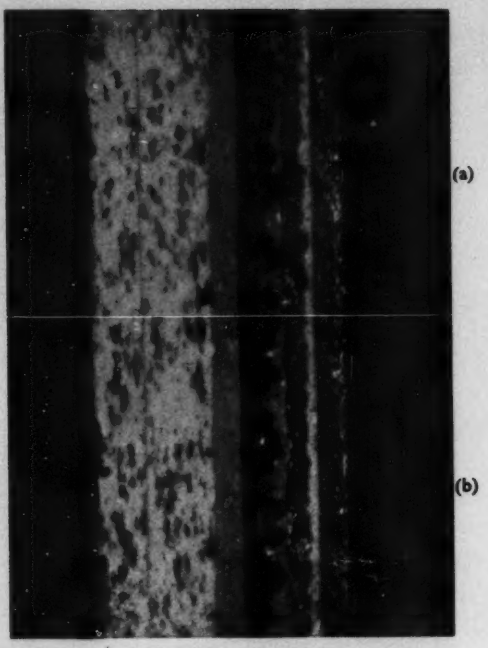


FIGURE 2 – *The damaged mudguard of the car illustrated in figure* 1 *had been repainted many times, as revealed by a section of the layer of paint on it, seen highly magnified at* (a). *A section of a flake of black-surfaced cellulose paint collected from the scene of the accident is shown at* (b). *The sequence of colours and the thickness of the layers proved identical with those of* (a).

and packing of material for laboratory examination. Detective officers are also given systematic instruction on the types of case in which help may be expected from the regional laboratories as part of the Government-sponsored detective training courses held in London and at a number of provincial centres. These lectures, given by the scientific and liaison officers, are followed by practical demonstrations and discussion, thus providing a valuable means of establishing a sound relationship between the scientist and the investigating officer. Informal talks on recent cases, and visits to the laboratories for the purpose of seeing work in progress, constitute additional methods of giving the officer an insight into the part the careful scientific examination of material may play in crime detection.

Experience has shown that the examination of the bulk of the material submitted to the laboratory falls within the realm of either chemistry or the biological sciences, although from time to time the help of the physicist and geologist is necessary.

The chemist, owing to the wide range of his subject and its many points of contact with other subjects, must necessarily play an important part. Toxicological examinations involve not only a knowledge of complicated and delicate analytical methods, and the recognition of both organic and inorganic poisons, but the ability to identify all kinds of drugs, including the many medicinally important organic synthetics. Other examinations will demand a similarly extensive knowledge of dyestuffs, paint pigments, and colours used in inks, cosmetics, and the like. In cases of arson and other types of incendiarism the ability to recognize all types of inflammable material, explosives, and explosives residues is essential. It is equally clear that much of this work will involve a knowledge of spectrographic technique and the examination of materials by methods involving the use of ultra-violet, infra-red, and X-ray apparatus. No one chemist can be expected to be competent to cover such an extensive field adequately, and this difficulty has been met by ensuring that the staffs of

FIGURE 3 – *A piece of detached cellulose, collected from the scene of the same accident, was proved to fit exactly on to the damaged mudguard.*

FIGURE 4 – *In figure 3 it will be seen that there is a light circular mark on the bare metal of the wing. This mark proved to match exactly one found on the under surface of another fragment of cellulose (the upper one in this illustration) found at the scene of the accident.*

FIGURE 5 – *This flake of cellulose was taken from the clothing of the dead cyclist and is here seen in what was presumed to be its original position on the mudguard. There is a partial fit along one edge, and identification was confirmed by comparison of scratch marks and spectrographic analysis.*

the regional laboratories between them include scientific officers who have special knowledge of tinctorial chemistry, explosives and inflammable materials, poisons and drugs, and such other branches of the subject as are likely to have an application to forensic work.

The range of case material requiring study by the biologist is equally varied and extensive. Typical examples are the identification of wood splinters and sawdust, fragmentary plant and animal remains, the undigested constituents of feeding stuffs, the hairs of various animals, fibres from textiles and cordage, bloodstains, seminal stains, and animal and plant parasites. Work of this character involves the establishment of an extensive collection of authentic specimens, and, frequently, the development of special techniques for purposes of detailed examination and comparison. A wide knowledge of plant and animal morphology, ecology, and taxonomy has been found to provide a most valuable background for forensic work.

Broadly speaking, it may be said that the object of the laboratory study of material submitted by an investigating officer is to connect a suspect, or the vehicle or implements in his possession, with the scene of a crime or the line of approach to or departure from the scene, or to test the accuracy or otherwise of statements made by individuals in whom the officer is interested. The laboratory examination may serve not only to complete a chain of evidence against a suspect, or prove that his story is false or grossly inaccurate, but may equally serve to clear him of suspicion and establish his veracity.

The aim of laboratory investigation must in all cases be impartially to record the factual findings and the reasonable inferences to be drawn from such findings. The findings are always available to the defence, and are supplied to them as a matter of course where they are likely to assist a prisoner. Quite apart from this, an expert engaged by the defence is always given every possible facility, subject to adequate safeguards, for making an independent examination of the material previously submitted to the forensic science laboratory, and of course may report the results of his examination to his clients.

Probably the simplest way of illustrating this aspect of the work of the laboratory is to describe a selection of typical cases, and the examples which follow will, it is hoped, serve that purpose. Both the data resulting from the police side of the investigation and those emerging from the study of material in the laboratory are included.

CASE I

A young married woman was returning from a dance one dark November night to her home on the outskirts of a small town. Some distance from the dance hall she was accosted by a soldier, but ignored him and went on. Immediately afterwards she heard the footsteps of someone coming up behind her, felt an arm thrown roughly round her neck from the back, and received two violent blows, one on the head and one on the shoulder blade. She struck out with a torch she was carrying and heard it hit something metallic which, she thought, was a button or belt buckle. This had the effect of preventing further molestation and she hurried home, where it was found that she had been stabbed on the head and in the back. Medical help was summoned and the police were notified. Beyond the town was an anti-aircraft gun site, and, since a soldier was implicated and since the route to the gun site was that also leading to the girl's home, a check was made on the troops who had been out on short passes that night. It was noticed that one of the men interviewed had several dark and sticky stains, resembling blood, on his clothing, and as his explanation of these was unsatisfactory he was detained. The following morning the scene of the assault was searched, and a small saw-edged knife with a broken blade was recovered. The fragment of blade was also found, and the two parts fitted together accurately and were clearly parts of the same knife. The exhibits submitted to the laboratory were the injured girl's outdoor coat (a greenish rough tweed), her pink rayon blouse, her torch, the soldier's battledress tunic and trousers, and the two parts of the broken knife. There was an obvious stab-cut through the coat and blouse in the region of the right shoulder blade, both of which were bloodstained. The blood, when grouped, proved to belong to Group AB. The stains on the soldier's uniform were due to human blood also belonging to the same group, and were of recent origin. Detailed examination of the knife showed that the tip was bloodstained on both sides, and that the blood was human and belonged to Group AB. The examination of the knife also revealed the presence of a considerable number of fibres caught up in the serrations of the blade. The majority of these were wool fibres of various shades of yellow and brown, with occasional red ones, and could be matched exactly with control fibres taken from the uniform of the suspect. Near the tip of the blade there were, in addition, wool fibres showing detailed agreement with those of the injured girl's coat, and pink viscose fibres matching those of her blouse. It was a reasonable inference from these findings that the knife was the weapon used, and that it had been in the possession of a soldier. Attention was next directed to the suspect's uniform, and on the left sleeve further wool fibres matching those of the girl's coat were found, together with two human head hairs showing detailed agreement with those of

the girl. Here then was a soldier suspect, who had stains of human blood of the same group as that of the injured person on his clothing, with other indications of contact, and who in all probability travelled back to camp along the route taken by her.

A final point which emerged from the laboratory end of the investigation concerned the torch. This showed a linear dent in the nickel casing, and traces of nickel were found along the fracture of that part of the knife blade which was still attached to the handle. It seems highly probable that, when the injured girl struck out with her torch, it hit the knife blade and fractured it, and that the knife was knocked out of the soldier's hand by a second blow, which resulted in the transfer of metal from the torch to the fractured end of the blade. The soldier was charged, tried, found guilty, and sentenced to imprisonment.

CASE 2

The case described below is of some interest in that laboratory examination served to connect two apparently unrelated offences. A saloon car was stolen from a garage in a South Wales town during the hours of darkness. Its loss was discovered almost immediately, and was reported to the police, who circulated its make, colour, registration number, and other relevant details. It was recovered the same night, with an empty petrol tank, on the outskirts of the town, and was dusted for finger-prints with negative results. The officer investigating the theft noticed, however, that there was an appreciable quantity of sawdust on the carpets covering the floor of the car. This was collected and, when examined at the laboratory, proved to be that of Scots Pine (*Pinus sylvestris*), probably the commonest and most abundant kind of sawdust in Great Britain. Its evidential value, taken alone, was therefore poor. There were, however, among the wood fragments numerous small, thin, irregular flakes of brown vegetable matter, which bore a superficial resemblance to broken bits of cigar leaf but which on detailed examination proved to consist of particles of the skin of new potatoes. Further police investigation led to the arrest of two youths, and pine sawdust with the same unusual extraneous plant tissue was recovered from their footwear and trouser turn-ups. This, with other information gathered by the police, served to connect them beyond reasonable doubt with the theft of the car. In the meantime a report was received that a Co-operative shop had been broken into and various articles and cash from the till had been stolen. The floor of the shop was covered with sawdust, which proved to be pine sawdust and contained particles of new potato skin derived from a large serving bin into which the sacks of potatoes were emptied. The accused were, on this evidence, charged with both the shopbreaking and the theft of the car: they pleaded guilty.

CASE 3

Although the poultry thief has always existed, systematic large-scale poultry thefts in Britain are one of the legacies of wartime food shortages. Chickens have always found a ready sale on the black market, especially immediately before Christmas, and expert thieves have developed a high degree of skill in stealing birds with the minimum amount of noise and disturbance. The following case will serve to illustrate some of the ways in which laboratory investigation may be helpful.

A lorry travelling towards London along one of the main roads from the south was stopped after midnight for routine check by a police motor patrol, and was found to have a number of crates of live fowls aboard. The driver, who was accompanied by a second man, mentioned the breed of the fowls, and stated that he had purchased them from a dealer, whose name and address he gave, at a town on the south coast. His driving and road fund licences and insurance certificate were in order, and he was allowed to proceed. Next morning the theft of a hundred and twelve pullets from a south-country breeder was circulated. A lorry had been driven into the field in which the fowls were housed, after the zinc-coated triple barbed wire strands surrounding the field had been cut and bent back. A short strip of rough-surfaced wood about five inches long was the only clue the raiders had left. The dealer from whom the lorry driver stated that he had bought the fowls was located, and proved to be a wholesale fruit and vegetable merchant. He stated that the lorry driver had called at his premises on the afternoon of the previous day and had begged some strips of wood from an empty fruit box for the purpose of mending defective fowl crates. He had not sold him any fowls. Meanwhile the address given by the lorry driver was visited and fowl dung and feathers were collected from the lorry. An almost new pair of stout wire-cutting pliers found on the lorry was also taken into possession. The fowls had vanished, but four were traced, and luckily their crops and gizzards were recovered. These, together with the pliers, the dung and feathers from the lorry, the cut strands of barbed wire, and samples of the food and grit supplied by the farmer to his pullets were submitted to the laboratory. The food consisted of a mixture of wheat, barley, and bran, with a smaller amount of oilcake. The oilcake consisted of a mixture of ground-nut seeds and palm kernel. Traces of all these feeding stuffs—a most unusual combination—were identified in the contents of the crops and in the dung from the lorry. The gizzards contained chopped flint grit agreeing with the sample supplied by the farmer. The piece of wood found in the fowl run was identified by the wholesale fruiterer as from one of his fruit boxes and, finally, in addition to traces of zinc on the blades of the pliers,

many of the slight imperfections in the cutting edges were faithfully reproduced on the cut ends of the strands of barbed wire. Evidence of these findings was given at the trial of the lorry driver and a conviction was recorded.

CASE 4

One of the commonest of the everyday problems posed to the police officers is that resulting from motor accidents in which a pedestrian or cyclist is killed or seriously injured, and in which the offending vehicle fails to stop. The case described in the following note is a typical example of this kind.

A cyclist travelling along a main road in the dusk of an autumn day was knocked down and fatally injured by a motor car which did not stop. The cycle suffered considerable damage, suggesting a severe impact, and this view was confirmed by the discovery of a sidelamp and a number of irregular flakes of black-surfaced cellulose paint at the scene of the accident. The car believed to be the vehicle concerned was traced: its nearside sidelamp was missing, and the nearside front wing was badly scored and dented and had lost a considerable quantity of paint. Some indication of this damage and of that to the cycle is shown in figure 1. The flakes of paint from the scene were collected, and these, the car, and the cycle were brought to the laboratory for detailed examination. The laboratory also received the clothing, footwear, collar, and tie of the deceased cyclist, and samples of his blood and hair. Inspection of the car revealed a number of details which might prove significant. A piece of rag which was wrapped round the leads of the missing sidelamp bore some dark reddish brown stains, and there were several hairs adhering to it. A number of blue fibres were found on the lower edge of the left-hand corner of the windscreen, and these appeared to be of about the same colour as the tie of the dead man.

None of these early finds proved helpful: the reddish brown stains on the rag were paint, the hairs were not human, and the blue fibres were cellulose acetate, while the tie was a blue woollen one. The only significant find in the clothing was a small angular flake of black-surfaced cellulose paint bearing a number of more or less parallel scratches. Careful measurements indicated that the offside pedal of the cycle must have been hit by the front of the car wing, and that the damage to the highest part of the wing had been caused in all likelihood by the metal framework of the saddle. The occurrence of traces of cellulose paint resembling that on the car wing, on both the ball-race cap of the pedal and on the metalwork of the saddle, provided some preliminary check on this interpretation.

It was evident that a detailed study and comparison of the fragments of cellulose paint from the road and from the car were the most promising fields for further study. Figure 2*a* is a photomicrograph of a section taken from a paint fragment removed from the car wing, and figure 2*b* is a photomicrograph of a section from a fragment collected from the road. Although the colours of the sections are not reproduced, the detailed agreement in the thickness and characteristics of the various layers is strikingly clear. The wings had evidently been repainted a number of times, and, in one instance, the addition of further coats of paint before a previous layer had dried had led to a wrinkling of the surface. Spectrographic analysis of the two samples gave identical results.

After exhaustive search, a small paint flake from the road was found, which gave an accurate fit with paint still present on the car wing. This fit is illustrated in figure 3, which also shows a circular mark on the bare metal of the wing immediately to the right. Figure 4 shows the juxtaposition of the above-mentioned flake with a second flake found on the road. Both are photographed from the under side, and part of the circular mark on the wing is shown in reverse on the right side of the upper flake. The evidence that the car under examination had been damaged on the road at a point where the accident had occurred was conclusive.

Attention was next turned to the flake of paint found on the clothing of the dead man, and figure 5 shows an enlarged photograph of this flake in what was assumed to be its original position on the car wing. There is a partial fit along one edge of the fragment, and the close agreement of the scratch marks and scoring of the paint, as well as a spectrographic analysis of the fragment, established beyond reasonable doubt that it had come from the car wing. Analysis of the paint on the metalwork of the saddle and the ball-race cap of the pedal completed the laboratory end of the investigation. The court held that the evidence that the car caused the death of the cyclist was conclusive.

The selection of cases described above, while serving to give some idea of the daily work of a forensic science laboratory, indicates only part of its activities. The members of the scientific staffs may be called upon either for advice to, or to undertake work for, various government departments where it is considered that their specialized knowledge and experience would prove helpful. They must read widely, and be alert to envisage possible applications of new research methods to their problems. They should, and normally do, undertake original work on those parts of their subject in which they are specially interested.

The forensic science laboratory is not for the man who seeks the calm of academic life, or for such as find that steady application in a limited field of study suits their temperament. It provides a career in which hard work, the urge of scientific curiosity, and infinite variety are the chief ingredients and, for the right type of scientist, it is both stimulating and satisfying.

Scientific education in the United States

F. A. PHILBRICK

American teaching of science, in spite of some recent criticism, is directed mainly to practical ends, with the result that relatively slight advances in pure science accompany unsurpassed progress in technology. In American pedagogy new material is presented in separate units, and is sedulously related to familiar experience. Instruction suffers at the lower levels from excessive numbers, but some institutions provide unequalled facilities at graduate level.

Many writers have noted that pragmatism is the chief trait of the American character, whether this is to be attributed to the cast of mind common in emigrants to the New World, or to the conditions of life that they found and developed there. And just as pragmatism has been the dominating philosophy taught in the universities, so in pedagogy has everything been subordinated to immediate and practical ends. In America, the battle for the inclusion of science in the curriculum was easily won. Money for laboratories has been generously provided—it has always been more readily available for buildings than for the men who teach in them—and the visible successes of modern science have given it enormous prestige as an academic subject. So greatly envied is the position of the scientist in the universities that his colleagues in other departments are tempted to describe their own subjects as sciences and themselves as scientists. Thus a historian who emigrates to America may find that he has become a *social scientist*, and in a recent book a psychologist goes so far as to say, 'Scientists study and write about people and the world in which they live'—a definition which seems to include all possible topics.

There are two ways of teaching physical science. One of them begins from the data, either those that were thought significant by early workers (the historical method) or those that are relevant today, and by induction derives the laws of nature. The other begins with the laws, and explains the data as deductions from them or as examples of their application. Whereas the inductive method aims at developing the mind of the student by helping him to organize the data, the deductive method presents him with the data already organized. This second method is universally followed in the United States, whose schools were scarcely touched by the heuristic movement that began in England half a century ago. Thus in an American chemistry course the laws of chemical combination may be presented as deductions from the atomic theory, and such a difficult point as the diatomicity of hydrogen molecules appears as an unaccountable act of intuition.

It is true that there are doubters. Jacques Barzun, in his brilliant and iconoclastic *Teacher in America*, [1] has a chapter on 'The Ivory Lab.' in which he says that science is the worst taught of all subjects. In advocating the historical method of teaching, he claims that the education of students as men and citizens is sacrificed in the colleges to vocational training, and that current methods have produced among the teachers themselves 'many highly trained and absolutely uneducated practitioners.' In his Terry Lectures [2], President Conant of Harvard, possibly the most influential scientist in America, likewise appeals to teachers of science for a new attitude to their subject deriving from some understanding of its history.

These, however, are exceptional views, and the character of American scientific achievement is a consequence of the pragmatic conception of scientific education. The unrivalled successes in technology, and the relatively unimportant contributions to fundamental knowledge, are consequences of the nature of American teaching. Geoffrey Gorer, whose book *The American People* [3] is the most penetrating study since de Tocqueville, is excellent on American science. He points out that basic inventions, whether radar, penicillin, or jet propulsion, are usually foreign, but that improvement, industrial adaptation, and above all diffusion are carried out in America with unique success. 'Make a better mousetrap, and the world will beat a path to your door.' It is improvement that is recommended, not novelty. 'Their attitude towards things,' writes Gorer of the Americans, 'is untroubled by ambiguity, serene and confident, audacious and creative to an extent that no other

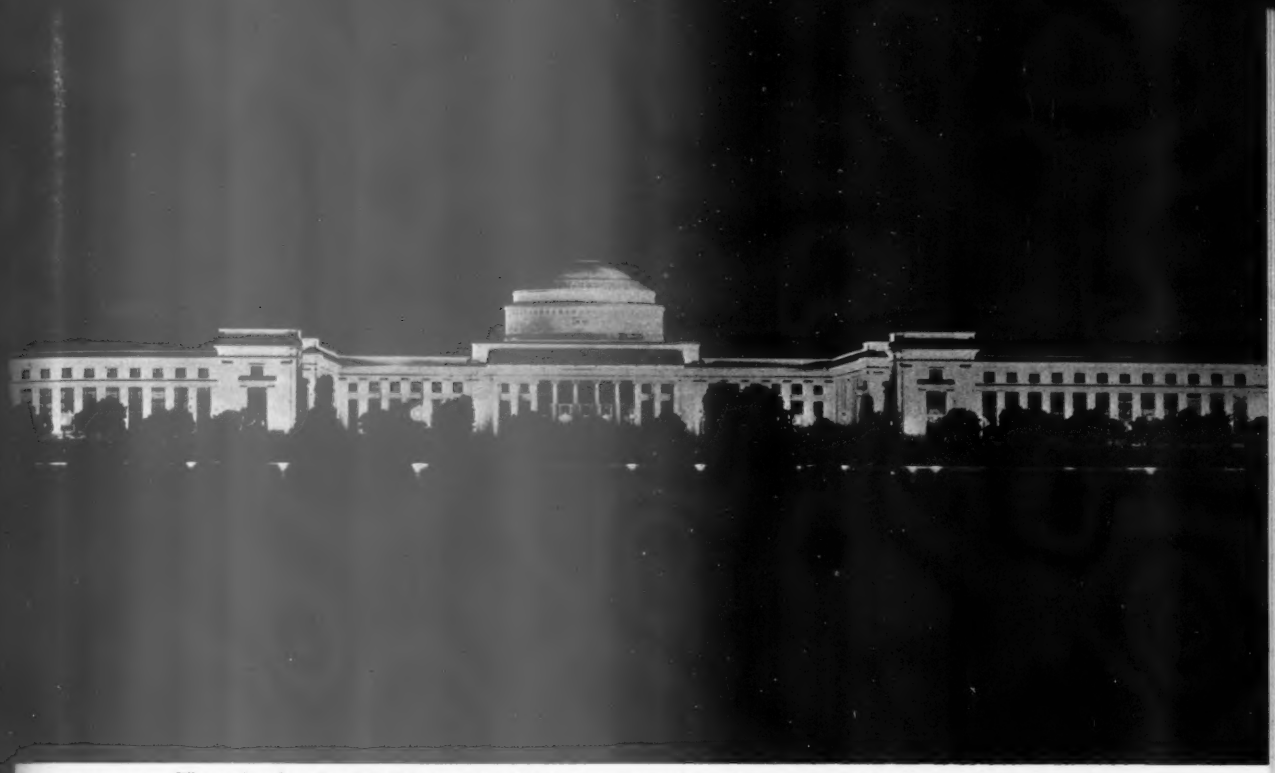


FIGURE 1 – *The main educational buildings of the Massachusetts Institute of Technology at Cambridge, Massachusetts, as they are seen from the Charles river at night.*

FIGURE 2 – *The Museum of Science and Industry at Chicago, on the shore of Lake Michigan, is visited by one and a half million people annually.*

society in the world has seen or imagined. . . . This ingenuity in the exploitation of things has, fairly recently, been given a special term—"know-how"; it is rightly considered peculiarly American.' The admiration accorded to science has in some degree protected science teaching from the encroachments of the athletic coach, the great enemy of education in America—before whom even college presidents are dumb. To the alumni the new laboratory block may be scarcely less an object of pride and interest than the stadium.

Two important pedagogical devices are used in America in presenting to untrained minds the complicated systems of the sciences. The first is a thorough correlation of the discussion with the experience of the student. Any European glancing through an American textbook of elementary science is impressed with the variety of illustrations designed to hold the interest of the reader, and by the pains taken in the text to connect the unfamiliar with the known. If the author is unskilful the device may lead to mere descriptive chitchat, but it is unusual to find an American text in which pedantry or a too rigorously mathematical treatment has kept the exposition above the levels of attention or understanding that can be expected of the reader. The present American eminence in thermodynamics, though perhaps partly derived from the great example of Willard Gibbs, may probably be attributed to the excellence of American textbooks on the subject, which never let the reader forget that this branch of science deals with the real world.

The second pedagogical device is the division of the subject into parts of manageable size. This plan is likewise much in the minds of authors of textbooks, and one may find a discussion of, say, respiration headed in bold type UNIT 17. To gain a rapid mastery of a topic it is undoubtedly wise to study one part of it at a time, and to finish that before going on to the rest, though by this method there may be some loss in total grasp. The efficiency of the method was demonstrated during the war by the success of the service courses which trained men to operate and maintain complicated scientific apparatus. It was perhaps inspired by another typically American technological improvement—mass-production, in which a manufacturing process is divided into separate operations that can be performed on an assembly line.

The fragmentation of the subject-matter of science in American teaching is encouraged by the institutions of the *course* and the *credit*, and by the objective examinations now in vogue. A student takes a number of courses, for instance Botany 1 or Qualitative Analysis, each lasting a year. When he has successfully completed the course he gets a credit for it, and when he has enough credits he graduates and receives his diploma. Once a particular course has been passed, a student need expect no further examination in its subject-matter; for comprehensive examinations in the whole of some branch of science are, if not unknown in the United States, at least uncommon. It is not surprising, therefore, that the essay-type examination, which tests the candidate's ability to correlate his knowledge of the different parts of a subject, has now been almost displaced by the objective test, consisting of a large number of separate questions often little related to each other.

The undoubted American talent for teamwork and organization relieves a teacher of science of much work that in Britain he would expect to do for himself. In America the duties of a junior instructor may be confined to explaining the textbook, supervising the laboratory work described in the manual, and correcting the objective examinations sent to him in bundles once or twice a month by the head of the department. The class work follows the order laid down in the textbook, which is begun by the teacher and the class on the first page and faithfully followed to the last, each division of the book being completed by all the classes on the same day. In large institutions the textbook, written by the teachers, often circulates for years in an edition produced by photography from the typescript and frequently revised until it is ready for printing and public sale. The system allows little initiative to the teacher, and departmental control is often strict. Instruction under these conditions, though usually efficient, is not stimulating either to teacher or to students, and the more enterprising teachers, if they cannot rise to positions where they have control over their courses, either take administrative work or go into research.

The institutions in which these ideas are put into practice range from the grade schools, through high schools and colleges, to the graduate and professional schools of the universities. The entire population attends at the lowest level, but only a small fraction of it at the highest. Great efforts are made to ensure that the selection for higher training is intellectual as well as financial. In science, for instance, the Westinghouse Corporation conducts an annual search of the high schools to make sure that the boys and girls of greatest promise are sent to college. The early

specialization usual in England is deplored by American teachers, and in high school it is most uncommon for any branch of science to be studied for more than two years, one-year courses in physics, chemistry, or biology being almost universal, and astonishingly uniform throughout the country in content and treatment.

The peculiarly American problem of higher education is, however, the presence in the colleges of great numbers of students little suited by taste or training for the academic life. Inspired by a generous desire to make higher education as nearly universal as it can be, the colleges long ago opened their gates to almost everyone who could pay the fees, and the prosperity of the country has multiplied the number of students. Most American private schools send nearly a hundred per cent. of their alumni to college. The state universities, almost entirely maintained by state funds, and hence exposed to political pressures, are in positions of special weakness against the invasion of the incompetent. The hard discipline of the sciences, however, has little to attract triflers, so that the departments of science suffer less than most from standards depressed by excessive numbers of mediocre students. But the methods of instruction have had to be adapted to them. The lecture-demonstrations, often given by the professor in charge of the course, may be attended by as many as two hundred, and the rest of the teaching is done in the laboratory and in small discussion groups conducted by junior teachers. Attendance at all these is obligatory for every student taking the course, and his progress through the year is followed by the marks that he receives in the frequent objective examinations.

In some colleges specially devoted to science the quality of the work is considerably higher than elsewhere. Chief among these are the Massachusetts Institute of Technology (see figure 1) and the California Institute of Technology, with its remarkable list of Nobel prizewinners from the faculty. These two colleges have high standards of admission, and every June the great industrial corporations are in eager competition for the services of their fortunate graduates. Only a few of the less specialized universities, Harvard among them, are able to offer scientific courses of this quality to undergraduates. If, however, the scientific education of undergraduates in most American colleges is admirable chiefly for the efficiency with which large numbers of indifferent students are given elementary instruction, many of the graduate schools are as good as can be found anywhere. The difficulties that at present beset the academic life in other countries have brought to America brilliant teachers and students from overseas, and a young graduate wishing to do research in the United States is unlucky if he cannot find at least one American university where he can work in perfect conditions and under a scientist of world reputation.

In this brief article only the outline has been traced of scientific education in America. It is impossible to give a fair description either of the great medical schools, or of such unique foundations as the Institute for Advanced Study at Princeton, directed by Robert Oppenheimer and with Albert Einstein on the faculty, or of the extraordinary Museum of Science and Industry at Chicago (see figure 2). After investigating such spectacular exhibits as a full-size working coal-mine, a visitor to this museum can witness a demonstration of sensitive apparatus such as the Michelson interferometer. This museum should be seen by all scientific visitors to the United States, who will find here and elsewhere that the traditions of American hospitality are fully shared by her scientists, and that libraries and laboratories are gladly thrown open to scientists from abroad.

REFERENCES

[1] BARZUN, JACQUES. 'Teacher in America.' Little, Brown & Co., Boston, 1945.

[2] Published in England as CONANT, JAMES B., 'On Understanding Science.' Oxford University Press, 1948.

[3] GORER, GEOFFREY. 'The American People.' W. W. Norton & Co., New York, 1948.

High-polymer molecules in solution

A. R. MILLER

Polymers not only dissolve in a way which cannot be accounted for by the ordinary thermodynamical theory of solution, but the solutions themselves do not even approximately obey the ideal laws. It has thus become necessary to develop a new mathematical theory which will take account of the complex interaction between polymer and solvent. The new theory is generally satisfactory, and such discrepancies as occur may be attributed to changes in the configurational properties of the individual polymer molecules with concentration.

Ideal solutions obey particularly simple laws. The partial pressure of a component of an ideal liquid mixture is directly proportional to the mole fraction of that component. Thus

$$p_i = p_{i,0} N_i \quad \ldots\ldots\ldots\ldots (1)$$

where $p_{i,0}$ is the vapour pressure, at the same temperature, of the pure species i; p_i is its partial pressure; and N_i is its mole fraction in the mixture. The other physical quantities whose values can be derived by thermodynamical argument from the partial pressure, such as the osmotic pressure and the depression of the freezing point, follow equally simple laws. These laws describe the behaviour of low-molecular substances in dilute solution. The quantitative significance of 'dilute' in this connection depends on the components of the mixture which is being examined. For some mixtures, the behaviour will be ideal up to quite high concentrations; for others, the behaviour will be ideal for only very small concentrations.

When a quantitative experimental study is made of solutions which contain high-polymer molecules, very great departures from all these simple laws are observed. It is a fact of common experience that in the presence of a liquid the behaviour of a high polymer, such as natural rubber, is markedly different from that of low-molecular substances. The latter dissolve readily in suitable solvents to a precise maximum concentration. On the other hand, high polymers first swell, imbibing liquid without themselves being dispersed. In a non-solvent nothing further happens, but in true solvents the polymer gradually loses its form and ultimately disperses to form a solution. This behaviour cannot be accounted for by the ordinary thermodynamical theory of solutions.

In the last decade, substantial advances have been made in the mathematical treatment of polymer molecules, and in particular in the development of the theory of solutions in which one of the components is a high polymer. In this particular field these advances have followed from the recognition that, in the language of statistical mechanics, a liquid must be treated as a co-operative assembly. An indication of the implications of this can be given fairly simply. In the simplest applications of statistical mechanics the interactions between the atoms or molecules (described briefly as 'systems') of which the assembly is composed can be neglected. Practically, what is meant by this is that those properties of such assemblies in which we are interested are found to be largely independent of the interactions between the constituent systems. Ideal solutions and perfect gases are among the best-known examples in this category. For instance, the usefulness of the gas scale of temperature lies in the fact that, in the limit of small pressures, the behaviour of gases tends to become independent of the properties of any particular gas—or, as we say, it approaches ideal behaviour. There are other assemblies in which there is a loose coupling between their individual systems, but this interactive coupling has no very profound effect on the properties of the assembly. It can be regarded as a perturbation which modifies the properties of the assembly only slightly. Slightly non-ideal solutions are in this category. There are, however, other assemblies in which the state of any system of the assembly is affected in a fundamental way by the particular states occupied by the other systems of the assembly. In these cases the interactions between the constituent systems of the assembly play a fundamental role, and exercise a dominating influence on the properties of the assembly. Ferromagnetic media, order–disorder transitions in alloys, critical conditions for the condensation of a gas or a vapour on to a solid surface, and solutions of high-polymer molecules are all examples of assemblies of this kind.

Before formulating the physical problem, it is

necessary to adopt a physical model of the assembly which, while being tractable mathematically, provides also a reasonably accurate description of the physical assembly. This we now proceed to do in the case of liquids, considering in particular the way in which our physical model can be used to represent a solution which contains high-polymer molecules. Since it was first realized that X-ray diffraction patterns could be interpreted to provide information about the structure of substances, many liquids have been examined in this way. These studies show that in a liquid there is a high degree of local order between a molecule and its near neighbours, but no long-range order as is found in a crystal. The geometrical relationship between a molecule in a liquid and those molecules in its immediate neighbourhood can be described by an average co-ordination number. There are fluctuations about this average which, while they do not impair the local order between a molecule and its near neighbours, are sufficient to destroy the long-range order. In the light of this picture we can imagine a quasi-crystalline array of sites, in which the geometrical relationship between a site and its closest neighbours is described by an average co-ordination number (which expresses the local order), while there is no regular geometrical relationship between sites at much greater distances.[1] In a liquid the molecules can be pictured as being distributed on such a quasi-crystalline array, this being the simplest picture which accords with the evidence from X-ray diffraction patterns. Thus the simplest useful model of an unassociated liquid is an aggregation of spheres packed together, not tightly, which would represent a crystalline solid, but not very far from tightly. Such a model has less order than a crystalline solid, but it retains a degree of order which is far different from the complete randomness characteristic of a gas. This physical model allows the individual molecules considerable freedom of movement while retaining a high degree of local order.

The extension of this quasi-crystalline model of a liquid to cover the case of liquid mixtures which contain high-polymer molecules is straightforward. A high-polymer molecule consists of a fundamental unit or segment which is repeated a large number of times to form the complete molecule. For example, rubber consists of a large number of isoprene units, each of which is about the same size as, for instance, a benzene or a toluene molecule. The complete 'molecule' of natural rubber consists of many thousands of isoprene units linked together to form a chain. In figure 1 a diagram of an isoprene unit is drawn to show the relative dispositions of the radicals of which it is built up, and also the orientation to one another of successive isoprene units. Natural rubber in the unextended state is fairly adequately represented by a roughly tetrahedral co-ordination of linked subgroups (or segments), with the distance between the centres of mass of neighbouring segments about 4·4 A. This can be compared in size with a benzene molecule, which in the liquid state is roughly an oblate spheroid having major axes of about 6·2 A and a minor axis of about 4·2 A. In considering a physical model of a solution of a high polymer, each solvent molecule can be allocated to one site on the quasi-crystalline array, while to each polymer molecule there must be allotted a large number of sites forming a connected path on the quasi-crystalline array. In fact, each segment of a polymer molecule can be allocated to one site on the quasi-crystalline array, successive segments of a molecule being allocated to closest neighbour sites on the array. Because the sites to which the segments of a polymer molecule are allocated must form a connected path through the array, according as the segments are linked together,

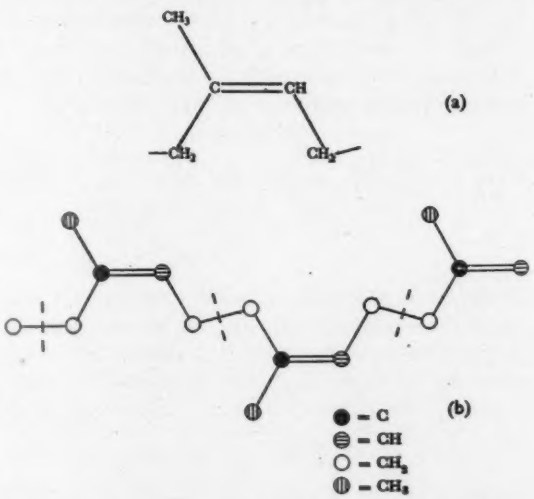


FIGURE 1 – (a) *Isoprene unit.* (b) *The way in which the isoprene units are linked together to form the rubber chain, successive isoprene units being differently orientated. The broken lines indicate the separate isoprene units.*

[1] It should be noted that, in this connection, the word 'order' is used to refer to the geometrical relationship between a small group of sites and not to the mode of occupation of sites on a regular crystalline array, as is the case in considering order–disorder transitions in alloys.

constraints are imposed on the occupation of sites which are near neighbours of one another. Mathematical analysis indicates that these constraints are of the same kind (from the point of view of statistical mechanics) as are introduced by interactions which affect the states of neighbouring molecules. These constraints can be taken into account in examining the physical model which has been described.

The statistical methods which are most appropriate for such a model are those which assume no more than a clearly defined local order between each molecule and its near neighbours. Such methods were first developed in the study of order–disorder phenomena in alloys by Bragg and Williams, by Bethe, and by Kirkwood. It is characteristic of these methods that the occupation of a small group of sites is considered in detail, and average values are used to consider the effect of the occupation of sites outside the group. In this way approximate grand partition functions[1] can be constructed. It is clear that these methods can be applied to a liquid mixture, and it was by using them that an unambiguous expression for the free energy of a high-polymer solvent system was first obtained.

In the first place it is worth while to consider solutions of high polymers in which the energy of mixing is zero. This has the advantage that the effect of the different sizes and shapes of the polymer and the solvent molecules is isolated. This proves to be particularly important, for it appears that the greater part of the divergence of solutions of high polymers from ideal behaviour is due to this cause. The result which was obtained for the free energy of a monomer-polymer system was:

$$\frac{(\Delta A)_{r,1}}{kT} = \tfrac{1}{2}z\{N_1 + qN_r\}\log\frac{N_1 + qN_r}{N_1 + rN_r} - N_1\log\frac{N_1}{N_1 + rN_r} - N_r\log\frac{N_r}{N_1 + rN_r} - \tfrac{1}{2}zqN_r\log q_r \quad \ldots\ldots\ldots(2)$$

where each polymer molecule consists of r segments, the mixture contains N_1 solvent and N_r polymer molecules, and q is a parameter which gives the number of closest neighbour contacts made by each polymer molecule and is defined by

$$qz = rz - 2r + 2,$$

where z is the average co-ordination number which specifies the local order. Also $(\Delta A)_{r,1}$ is the free energy of mixing defined by

$$A = A_1 + A_r + (\Delta A)_{r,1}$$

where A, A_r and A_1 are the free energies of the solution, of the pure polymer and pure solvent species respectively. From this expression, the vapour pressure curves can be determined by taking the usual conditions for the thermodynamical equilibrium between a liquid and its vapour. The vapour pressure equations are:

$$\frac{p_1}{p_{1,0}} = \frac{N_1(N_1 + rN_r)^{\frac{1}{2}z-1}}{(N_1 + qN_r)^{\frac{1}{2}z}} \quad \ldots\ldots(3)$$

$$\frac{p_r}{p_{r,0}} = \frac{N_r(N_1 + rN_r)^{(\frac{1}{2}z-1)r}}{(N_1 + qN_r)^{\frac{1}{2}zq}} \quad \ldots\ldots(4)$$

where p_r and p_1 are the partial pressures of the polymer and the solvent respectively above the solution and $p_{r,0}$ and $p_{1,0}$ are the vapour pressures of the two pure species at the same temperature. The shape of these vapour pressure curves is shown in figure 2. The straight line represents the relation between the vapour pressure and the volume concentration in the solution for a mixture of roughly spherical molecules of equal sizes, and with negligible energy of mixing. The effect of the differences in the sizes and shapes of the molecules of the components is shown by curves (*a*), (*b*) and (*c*), which represent the vapour pressure curves for monomer-dimer, monomer-trimer and monomer-polymer mixtures respectively. It can be seen that even comparatively small differences in the sizes of the molecules of the two components [curves (*a*) and (*b*)] produce appreciable departures from the laws of ideal solutions. When the polymer consists of several thousand segments [curve (*c*)] the departure is very great indeed. The circles in figure 2 represent the experimental points obtained for rubber-benzene mixtures. It is clear that this simple theory, which takes account only of the differences in the sizes and shapes of the molecules of the component species, accounts for the greater part of the departure of polymer-solvent systems from ideal behaviour. Equally good agreement is shown when the theory is compared with the experimental results which have been obtained

[1] A partition function is simply a convenient mathematical way of describing the distribution of the energy over the states of the assembly.

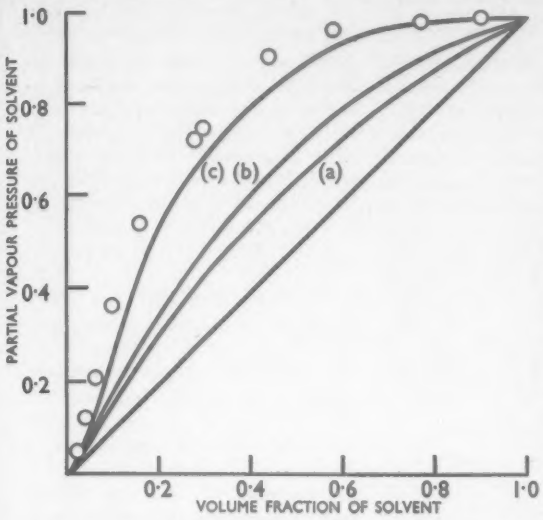


FIGURE 2 – *The partial vapour pressure as a function of the volume concentration of the solvent. The straight line is for an ideal solution, and curves* (a), (b), *and* (c) *respectively are for monomer-dimer, monomer-trimer, and monomer-polymer mixtures. The circles represent the experimental results for rubber-benzene mixtures.*

with other polymer-solvent systems, such as polystyrene-benzene and polystyrene-toluene. The theory has also been able to account for the experimental results which are obtained on the absorption of vapours by high polymers. In this case the molecules of the vapour take the place of the solvent in the liquid mixtures.

More detailed analysis of the experimental results shows that in the region of dilute solution there is some divergence between the theory and the experimental results. This discrepancy cannot be accounted for by the introduction of a non-zero energy of mixing, which has been shown to have a comparatively insignificant effect. Nor is it accounted for by the implicit assumptions of the physical model, which are implied by the use of an average co-ordination number, or the allocation of one site to a benzene (solvent) molecule or to a polymer segment. Neither of these assumptions has any appreciable effect. There is, however, another effect which should be noted. Whereas in solutions of moderate concentration the polymer molecules intertwine and are distributed throughout the liquid phase, in dilute solution they tend to be segregated. Their flexibility about their bonds then makes it possible for the polymer molecules to coil up and to form clusters. This profoundly alters the number of polymer solvent contacts, which in turn affects the variation of the heat of dilution with molar concentration. In the theoretical treatments which have been developed so far, it is tacitly assumed that the configurational properties of the polymer molecules are independent of their concentration in the solution. A study of the configurational properties of polymer molecules as affected by their concentration in solution, and of the consequent effects on the thermodynamical quantities which describe the solution, has yet to be undertaken.

REFERENCES

(*a*) GENERAL

FOWLER, R. H. 'Statistical Mechanics,' second edition. Cambridge University Press, 1936.

MILLER, A. R. 'The Theory of Solutions of High Polymers.' Clarendon Press, Oxford, 1948.

(*b*) METHODS OF EVALUATING PARTITION FUNCTIONS

(*i*) *Method of local configurations*

BETHE, H. A. *Proc. Roy. Soc.*, A, 150, 552, 1935; CHANG, T. S. *Ibid.*, A, 169, 512, 1939; MILLER, A. R. *Proc. Camb. Phil. Soc.*, 38, 109, 1942; *ibid.*, 39, 54, 1943; *ibid.*, 42, 292, 1946; RUSHBROOKE, G. S. *Proc. Roy. Soc.*, A, 166, 296, 1938; KIRKWOOD, J. G. *J. Chem. Phys.*, 6, 70, 1938; BETHE, H. A., and KIRKWOOD, J. G. *Ibid.*, 7, 578, 1939.

(*ii*) *Method of chemical kinetics*

GUGGENHEIM, E. A. *Proc. Roy. Soc.*, A, 148, 304, 1935; *ibid.*, 183, 203, 1944; ORR, W. J. C., *Trans. Faraday Soc.*, 40, 320, 1944.

(*iii*) *Statistical method*

MILLER, A. R. *Aust. J. Sci. Res.*, A, 1, 319, 1948.

(*c*) EXPERIMENTAL DATA

GEE, G., TRELOAR, L. R. G., and ORR, W. J. C. *Trans. Faraday Soc.*, 38, 147, 276, 418, 1942; *I.R.I. Trans.*, 18, 266, 1943; *Trans. Faraday Soc.*, 40, 463, 1944; *ibid.*, 41, 340, 1945; *ibid.*, 42, 507, 1946.

BAUGHAN, E. C. *Trans. Faraday Soc.*, 44, 495, 1948.

BARRER, R. M. *Ibid.*, 43, 3, 1947.

Book reviews

CHEMOTHERAPY

The Basis of Chemotherapy, *by T. S. and Elizabeth Work. Pp. xx + 435, with numerous line diagrams. Oliver and Boyd, Edinburgh and London.* 1948. *26s. net.*

In the epilogue to this book the authors claim that chemotherapy as a science has reached the transition stage in which theory has overtaken fact and is beginning to shape the future. How immense already is that body of factual matter and how bewildering is its complexity, with ramifications in many fields of physical and biological science, is probably not appreciated even by those who know something of recent spectacular advances such as sulphonamides, Paludrine, and the various vitamins. The extremely interesting historical introduction will therefore be invaluable for readers who wish to obtain a general survey of the development and present position of chemotherapy. The chapters which follow on cell metabolism, essential metabolites, enzyme inhibition, drug antagonism, drug resistance, and the relation between structure and activity of drugs, provide impartial and well-documented accounts of recent work for those who require more detailed information. In reading the book, which cites in its references nearly a thousand original papers, one is struck by the complexity of the problems, the difficulty of the experimental techniques, and the extreme ingenuity with which the various investigators have sought for solutions or partial solutions. From this wealth of material the authors have extracted the salient features, and have presented them so clearly that their book will be of special value to all who wish to pursue chemotherapeutic studies but whose fundamental training has been in one of the many sciences on which chemotherapy draws. The book is excellently produced, with clear diagrams and easily legible formulae. E. L. HIRST

STREPTOMYCIN

De Koch a Waksman: La Estreptomicina y la Lucha contra el *Mycobacterium tuberculosis, by Florencio Bustinza. Pp. xvi + 269. Espasa-Calpe, S.A., Madrid.* 1948. *120 ptas.*

The scope of this book is wider than its title indicates. Besides containing a clear and detailed account of the history, manufacture, and medical application of streptomycin, it gives also an excellent survey of antibiosis and antibiotics generally. The literature references are very comprehensive and cover every branch of the subject—medical, pharmaceutical, and chemical. Without in the least indulging in the sensationalism which has characterized much popular writing on this subject, Professor Bustinza has recognized its dramatic side, and has successfully contrived to write this into a precise and scholarly account of streptomycin and other antibiotics. At a time when such great interest is being taken in these substances the appearance of this book will be generally welcomed.

ELECTRONIC THEORY OF ORGANIC CHEMISTRY

The Electronic Theory of Organic Chemistry, *by M. J. S. Dewar. Pp. x + 324. The Clarendon Press, Oxford.* 1949. *30s. net.*

It is more than ten years since any British chemist has published a book dealing with the electronic mechanisms of organic reactions. The intervening period has seen such important developments as the Hughes-Ingold study of the essential differences between unimolecular and bimolecular reactions, and the detailed application of wave mechanics to the elucidation of structural problems. Since Dr Dewar has considered the main implications of all these advances, Sir Robert Robinson, in a four-page foreword, justly commends the book to students as 'the best available account of modern theories of the mechanism of the reactions of carbon compounds.'

Dr Dewar develops his concepts in terms of molecular orbitals, and shows that this treatment accords with the fundamental theories of Lapworth and Robinson. He has rendered organic chemists a valuable service by breaking away from the static 'resonance state' phraseology of Pauling and Wheland, which has, in several recent American publications, obscured the full implications of the essential differences between the normal and the reacting states of organic compounds.

Unfortunately Dr Dewar has written his book far too hastily. He is candid enough to admit in his preface that he does not accord to individual chemists due priority for their ideas, and he quotes so few references that the source and accuracy of his statements often cannot be checked. Those conversant with the subject will encounter many examples of misquotation of fact, and of misrepresentation of ideas, which seriously detract from the merit of the book as a whole. It is, however, so stimulating to read that it is hoped that a second, carefully corrected, edition will eventually be published.

W. A. WATERS

ELECTRIC DISCHARGE LAMPS

Discharge Lamps for Photography and Projection, *by H. K. Bourne. Pp. xv + 424, with many illustrations and tables. Chapman and Hall, London.* 1948. *36s. net.*

Electric discharge devices, until recently familiar only to the scientist and the engineer, are now commonplace, even if still incomprehensible, to the ordinary man and woman.

The author of the book under review has considerable qualification and experience as a research worker in this field. The book deals mainly with electric discharge lamps available in England, although there are sections on American fluorescent and flash discharge lamps. The chief electrical and luminous characteristics of discharge lamps are fully described, with emphasis on their photographic and projection use. The title of the book is somewhat misleading and might usefully have included a reference to 'other sources' to cover carbon arcs, which are not discharge lamps in the conventional sense, and incandescent filament lamps.

In this book there is collected together a great deal of information of considerable value to all interested in discharge lamps, whether for photographic purposes or the much more important applications in the field of illuminating engineering. It cannot be said that it is free from fault: the arrangement and presentation of the material are open to criticism. For example, the subject of fluorescence is, for no very good reason, discussed in two different chapters. Again, high-intensity flash-discharge tubes are included in a chapter with photo-flash lamps, which are not strictly speaking electric discharge lamps at all. It is surprising to find no mention of the historically interesting and still important method of spark photography. The use of flashing discharge lamps for photographically recording the finish of races also is not mentioned.

Bibliographical and patent references are given at the end of each chapter. There is a great deal of needless repetition, and much space would have been saved by recording each reference once only at the end of the book. The reproductions are numerous and for the most part good. The publishers are to be congratulated on the high quality of the paper and printing used in this useful book, which should find its way into the hands of all interested in electric discharge lamps. H. G. JENKINS

INDUSTRIAL WASTE WATER

The Treatment and Disposal of Industrial Waste Waters, *by B. A. Southgate. Pp.* 327, *with several line diagrams. His Majesty's Stationery Office, London.* 1948. 12*s.* 6*d.* net.

The purification of sewage and industrial wastes is a vital problem today and the setting up of each new industry brings with it fresh complexities to be overcome. It is thirty-five years since a book on the treatment of industrial waste waters has been published in Britain, and there is no man better fitted to undertake the task than Dr Southgate, Director of Water Pollution, Department of Scientific and Industrial Research. This establishment daily tackles new problems arising from industrial wastes, and carries out research into the treatment of industrial wastes and prevention of water pollution. In addition the author has at his disposal data from papers published in Great Britain and elsewhere, as his department publishes summaries on the treatment of waste waters.

After a discussion of the effect of pollution on the use of water and on fish, chapters are devoted to modern treatment of sewage and general principles of treatment and disposal of industrial waste waters. Then follows the treatment of special industrial liquors. Each industry is first described in simple language to enable the reader to appreciate the processes involved and the trade terms in common use; then follows the main theme of treatment and disposal of waste discharges produced by each process.

Chemical analyses are expressed in parts per 100,000, but it is hoped that in future editions of this book, of which indeed there will be many, the author will reconsider his decision and express the analytical results in parts per million.

Quite apart from its scientific value to a wide field of workers, the author has produced a book which is extremely readable and of absorbing interest, even to those who are not fully conversant with all the specialized processes involved.

E. WINDLE TAYLOR

ELECTRONS AND METALS

Electrons, Atoms, Metals, and Alloys, *by William Hume-Rothery. Pp.* 377, *with numerous half-tones and line illustrations. Louis Cassier Company Limited, London.* 1948. 25*s.* net.

Dr Hume-Rothery recently wrote a book entitled *Atomic Theory for Students of Metallurgy*, and was alarmed to find that this book, written and suitable for the honours student, was largely unintelligible to a number of senior industrial metallurgists. The present work is an attempt to present the modern electron theory of metals to readers who are intelligent and well versed in classical metallurgy but have neither the time for long periods of uninterrupted study nor the mathematical background which the modern student is assumed to possess. Dr Hume-Rothery has cast it in the style of a dialogue between an Older Metallurgist and a Younger Scientist. By this device, and by concentrating on the basic physical principles, he is able to give a very satisfactory account of modern theories in a readable form. It was inevitable that the book should be longer than an orthodox text covering the same ground. The exposition gains greatly from the 165 figures, which are admirably selected, although some of the microphotographs bear no indication of the magnification. Most of the topics treated are covered by the standard books on the electron theory of metals, but the detailed discussion of the factors governing constitutional diagrams will be new to many readers. There is a chapter on plastic deformation, but in general only the equilibrium properties of metals and alloys are considered, and such problems as the kinetics of precipitation are not discussed. F. R. N. NABARRO

SPECTROSCOPY OF FLAMES

Spectroscopy and Combustion Theory, *by A. G. Gaydon. Pp. xii* + 242, *with* 4 *plates. Chapman and Hall, London. 2nd Edition.* 1948. 25*s. net.*

The first edition of this interesting book was published in 1942. It provided a readable account of the principles underlying the application of spectroscopic methods to the study of flames and other kinetic systems, a useful bibliography, and a clear discussion of the contributions made by spectroscopy to the elucidation of certain restricted problems—such as the afterburning of carbon monoxide, on which Dr Gaydon's work has thrown particular light.

A chapter on continuous spectra and the role of atomic oxygen in combustion has now been added, and elsewhere the results of recent experimental work have been included, so that the present edition is longer by some fifty pages than its predecessor, more fully illustrated, and correspondingly more expensive.

This new edition does not warrant any modification of the conclusion—disappointing to a spectroscopist—that the fruits of this method are won hardly, if at all. It seems that the secrets of such complex problems as the burning of hydrocarbons are likely to be unravelled only by joint attacks with all available techniques. To see how little—and how much—may be expected of the spectroscopic contribution one cannot do better than to read this book. R. F. BARROW

FUNDAMENTALS OF PHOTOGRAPHIC THEORY

Fundamentals of Photographic Theory, *by Thomas H. James and George C. Higgins. Pp.* 286. *Chapman and Hall, London.* 1948. 21*s. net.*

The inside of the dust jacket describes this book as 'written for the camera fan as well as for the specialist . . .,' but that must not be taken to mean that it is the usual sort of popular science book about photography. It presupposes a quite extensive knowledge of physics and chemistry on the part of the reader. The authors have wisely limited themselves to discussing the physical and chemical reactions involved in making black-and-white photographs by the use of silver salts. Colour photography is not considered, except incidentally, and then only to the extent of a few paragraphs in the chapter on developer reactions. No attempt has been made to include any discussion of lenses or camera design, which, as the authors explain in the preface, they regard as a separate subject. This decision is one with which few will quarrel, as there have been far too many books on photography which, by trying to cover too much

ground, end by being either too detailed or too superficial. By limiting their terms of reference the authors have avoided these pitfalls and produced a book which is both readable and worth reading. Each chapter is followed by very complete references and there is an excellent index.

As one of the 'camera fans' mentioned on the dust jacket, your reviewer has derived great pleasure and learned a good deal by reading this book. It can certainly be recommended to photographers with a scientific background, and to others who want a general picture sufficiently well documented to enable any particular point to be followed up.

PETER A. LE NEVE FOSTER

COLLOIDS

Colloid Science, *by A. E. Alexander and P. Johnson. 2 vols., pp.* 837, *with numerous line drawings and diagrams. Oxford University Press, London.* 1949. 60*s. net.*

This book is an outstanding contribution to the literature of colloids, indeed it is probably the first comprehensive treatment of the subject in the light of modern physical chemistry. The first three chapters give an excellent general introduction to the subject; they are followed by thirteen in which different topics are treated thoroughly, both theoretically and experimentally. Some parts of the theory are difficult, but the authors skilfully assume only such prior knowledge as may reasonably be expected of an honours student in chemistry, explaining more advanced theory in the book. Only a few points can be mentioned in a short review; the application of thermodynamics, the theory of strong electrolytes, electrophoresis, and Brownian motion to colloids seem especially good; and the accounts of modern experimental methods and results are excellent and very well selected. There follow three chapters on surfaces, too short to cover the subject properly, but good particularly on modern experimental techniques for studying monolayers. The second volume contains nine descriptive chapters on rather disconnected subjects—dilute sols, gels and pastes, foams, emulsions, colloidal electrolytes, clays and zeolites, proteins, polymers, and membranes. There is a lot of useful information in these chapters, but for a thorough knowledge the larger monographs on some of these topics will be required.

The style is clear and readable, though occasionally reminiscent of rapid notes. The book is one of the very few thorough textbooks on colloid science. It lacks the majestic sweep of Freundlich's *Kapillarchemie*, but its physicochemical treatment is far more modern, and an immense amount of ground is covered.

N. K. ADAM

BRITISH PLANTS

Drawings of British Plants, *by Stella Ross-Craig. Part I, Ranunculaceae, pp.* 6 + 44 *uncoloured plates; Part II, Berberidaceae, Nymphaeaceae, Papaveraceae, Fumariaceae, pp.* 6 + 22 *uncoloured plates. G. Bell and Sons Limited, London.* 1948. 6*s. and* 4*s.* 6*d. net respectively.*

These are very pleasant drawings, well printed on good paper. This is saying a good deal, considering modern conditions. Mis Ross-Craig's series includes no descriptive text, but there are a foreword by Sir Edward Salisbury and an introduction by the artist. The illustrations are produced from clear line drawings which show whole plants or parts of plants natural size, accompanied by enlargements of critical features, and sometimes (where the plant is large) by small-scale drawings to show the habit. They quite merit Sir Edward Salisbury's claim that they are 'a happy combination of artistic portraiture and scientific accuracy of detail that should appeal alike to those who use them either as aids to identification, as scientific documents, or for aesthetic pleasure.' It will be a surprise to some readers to learn that, despite the large number of books in existence which deal with the British flora, 'there is still no complete series of drawings of our native flowering plants giving detailed analyses as well as a life-size portrait of each species'; yet such is the case, and it is much to be hoped that the present series will achieve completion. It aims at including all the clearly defined species native to the British Isles, and aliens which have become or are becoming established over a wide area. The parts are rather expensive, but this is made up for by the quality of the paper and printing.

T. A. STEPHENSON

SCIENCE IN FILMS

Science in Films, *edited by Blodwen Lloyd, M.Sc., Ph.D. Pp.* 238. *Sampson Low, Marston and Company Limited, London.* 1948. 15*s. net.*

The development of the documentary as distinct from the theatrical film during the last twenty years has been a British-led achievement. Films about fact have been made in their thousands, and have been presented in every conceivable way, depending upon the purpose for which they have been made. It is in this choice of the way in which a factual subject has been treated that distinguishes the documentary from the purely scientific film. The documentary tends to be more fanciful in its approach in order to 'put over' fact in an entertaining way; the scientific film treats its subject more dispassionately.

Science in Films, however, covers a range much broader than the purely scientific film. It is a review of the present situation regarding films that have been made with science as the subject matter. As such it is an invaluable book of reference for the scientist and educationalist, the interested layman, and the professional film-maker himself. Chapters by experts review the modern techniques available for the treatment of scientific subjects, including, for example, an excellent chapter on cineradiography. There is, in addition, a section collating information about films on science produced in every country, and about organizations interested in this type of film.

Dr Blodwen Lloyd's book is a reference work that was badly needed in a world where visual aids are being used increasingly for every form of education and information.

J. G. COOK

STRESS ANALYSIS

The Measurement of Stress and Strain in Solids. (*Report of a Conference held in Manchester,* 11*th,* 12*th, and* 13*th July,* 1946.) *Pp. xvi* + 114, *with* 33 *illustrations and* 8 *plates. The Institute of Physics, London.* 1948. 17*s.* 6*d. net.*

This timely volume is a reflection of the growing interest shown in the techniques employed in the measurement of elastic properties—an interest which resulted in the formation in the U.S.A. of a Society for the Study of Experimental Stress Analysis (1942). The result of the Manchester conference has been the formation of a group within the British Institute of Physics devoted to the same end, and the report may be regarded as their inaugural contribution. Some of the papers (such as the late Mr. Eric Jones's paper on physical characteristics of wire resistance strain gauges) are

critical surveys of selected fields. Photo-elasticity naturally bulks largely in modern stress analysis, and Mr Fisher's account of some recent photo-elastic developments is a contribution of outstanding interest. Other topics treated are the use of X-rays in the measurement of strains and residual stresses, and high-frequency and acoustic strain gauges. All the topics handled are of great interest to experimenters, but the value of an already valuable volume would be greatly enhanced were it to contain a brief account of the basic principles of photo-elasticity.

The volume is a notable addition to the 'Physics in Industry' series published by the Institute of Physics.

ALLAN FERGUSON

CORROSION OF METALS

Corrosion Handbook, *editor-in-chief Herbert H. Uhlig. Pp.* 1188, *with several half-tone illustrations and line drawings. John Wiley and Sons Inc., New York; Chapman and Hall Limited, London.* 1948. 72*s. net.*

This is not an encyclopaedia, and it is not a handbook in the accepted sense. It falls between the two as a most scholarly presentation of scientific and technical information in the form of separate chapters, each written by a specialist with an international reputation. It very fully treats the theory of corrosion, passivity, and oxidation; the liquid and gaseous corrosion of all the industrial metals and alloys; scaling at high temperatures; and the methods for corrosion protection and testing. There are a glossary, an index, and a large number of tables. The book is practical.

Mechanical effects in corrosion, as exemplified by stress corrosion, corrosion fatigue, and frettage corrosion, are well—if all too briefly—treated. Twenty-seven pages are hardly enough for a series of phenomena which, collectively, are responsible for most service breakdowns.

This book will be welcomed by all industrial research libraries and laboratories, as well as by many practising engineers, chemists, and consultants.

A. J. GOULD

SOIL FERTILITY

Pioneers of Fertility, *by Crichton Porteous. Pp. vii* + 125, *with* 46 *illustrations by Michael Ayrton. Fertiliser Journal Ltd., London.* 1948. 10*s. net.*

Crichton Porteous, novelist of the Adrian Bell school, has made a chronological series of studies of the men who have led us, stage by stage, along the road of expanding soil fertility. Here are Fitzherbert and Tusser; Townshend, Tull, Young, and Coke; Liebig, Lawes, and Gilbert; and many others whose names may be less widely known but whose contributions were no less heroic. 'Heroic' is not an ill-chosen word, for the novelist's instinct in Porteous has emphasized the struggle that almost all of them had to sustain against reaction and prejudice, custom and complacency.

Scientists and practical men follow one another in this delightful procession. Liebig is preceded by John Knight and his son, who left the profitable iron industry to wage a sixty-year reclamation battle with the Exmoor wilderness. And who knows today of John Mechi, a razor-strop magnate who turned to farming as an investment, became a fervent propagandist of new methods, and then lost all he possessed in the first 'cheap food' depression of home agriculture? The theme of the book is the evolution of our modern practices, but there is another theme between its lines—nearly all these men were individualists, fierce or patient. A first-class book for all classes of readers

DONALD P. HOPKINS

SCIENTIFIC INSTRUMENTS

Scientific Instruments II, *edited by H. J. Cooper. Pp.* 306. *Hutchinson's Scientific and Technical Publications, London.* 1948. 30*s. net.*

This well-produced book gives short descriptions, with numerous illustrations and diagrams, of some 150 physical instruments or instrumental systems. They are discussed under seven headings: optical, astronomical and navigational, electrical, electronic, material testing, recording, and miscellaneous, the last containing chapters on ship and aircraft model testing, computing machines, and instrument design. It will be seen that the selection presented is a fairly heterogeneous one, and the editor explains that the intention is to interest the student or scientific worker in some of the instruments in use in fields other than his own, and possibly inspire him thereby, rather than to supply detailed information for the specialist. Some of the chapters will be fairly successful in this aim, provided the reader is comparatively ignorant of the subject; if he has even a nodding acquaintance with it he will probably find that the necessarily rather scanty descriptions tell him little more than he has acquired by general reading, and his interest will be confined to the excellent photographs of modern instruments. There are one or two exceptions to the foregoing, notably the brilliant little essay on computing machines. The editor would have been well advised to omit completely the sketchy account of nuclear disintegration apparatus, however great its topical interest, since much better simple accounts exist. The space occupied by the chapters on electrical measurement and valve circuits would have been more usefully employed in giving references to any of a score of standard works.

B. M. CROWTHER

ZOOLOGICAL DIAGRAMS

Practical Zoological Illustrations, Invertebrates, *by W. S. Bullough. A portfolio of* 32 *cards. Macmillan and Company Limited, London.* 1948. 15*s. net.*

These illustrations, printed on separate cards (37 × 24 cm), are designed to help in the practical examination of those invertebrates that are studied in school and first-year university courses. The author states that he was stimulated into producing them by the inadequacy of many textbook illustrations.

All the figures are semi-diagrammatic and are very fully and clearly labelled; a brief paragraph of practical instructions accompanies each. The author anticipates the criticism that students will be tempted to draw from the figures, instead of from the specimens, by pointing out that it is the instructor's duty to emphasize the importance of individual effort and to teach the proper use of books.

The author first prepared these diagrams for use in his own class, and his students found them so helpful that he now makes them available to others. If properly used they will adequately fulfil their purpose.

L. HARRISON MATTHEWS

PATHOGENIC FUNGI

Biology of Pathogenic Fungi, *edited by Walter J. Nickerson. Pp. xx* + 236. *Chronica Botanica Company, Waltham, Mass., U.S.A.* 1947. $5 *net.*

The reputation of the *Annales Cryptogamici et Phytopathologici* whets the appetite aroused by the title of its latest volume, *Biology of Pathogenic*

Fungi. The first disappointment is in finding that the great majority of pathogenic fungi—those attacking plants and animals—are omitted; the volume deals only with those living on man. The recent work on the nutrition, respiration, and metabolic products of these fungi is covered by Dr Nickerson in a well-balanced 60-page survey. The remaining 150 pages of text have been contributed by twelve authors, who treat in turn of the *Torulopsidoideae*, of chromoblastomycosis, of *Pityrosporum ovale*, of coccidioidomycosis, of Italian 'mycopathology' in 1941–5, of the action of sulphonamides and antibiotics, of the geographic distribution of certain fungus diseases of man, and of the lipids of fungi. Each author starts afresh with his numbering of figures and tables, emphasizing the fact that these contributions are bound together only in the physical sense. It is not without sympathy that one reads the cautious conclusion of Dr J. G. Hopkins' foreword: 'The volume . . . will furnish a useful summary of what has been accomplished in the fields summarized.'

R. W. MARSH

STATISTICS IN INDUSTRY

Statistical Methods in Research and Production (with special reference to the Chemical Industry). *Edited by Owen L. Davies. Pp. xii + 292. Published for Imperial Chemical Industries Limited by Oliver and Boyd, London.* 1947. 28*s. net.*

This volume, prepared by members of the statistical staff of Imperial Chemical Industries Limited, is an important addition to the range of elementary statistical texts. The value to industrial chemists of techniques originally developed for biological data is illustrated by examples from experimentation and routine testing, always with emphasis on the interpretation of the statistical analysis, not merely on mathematical theory or computational procedure. The reader who studies the methodological discussion and the worked examples should have thereafter both understanding of estimation, significance tests, variance and regression analysis, and sampling, and ability to apply the statistical processes for himself. Two chapters on control charts show clearly the natural development of quality control from elementary sampling theory.

The classification of types of regression equation does not seem entirely satisfactory, and the discussion of their errors may increase rather than decrease confusion. An excellent chapter on sampling is marred by description of both stratified random and systematic sampling as *representative sampling*, so obscuring important distinctions in error estimation. These are minor blemishes, however, on a work notable for systematic development, clarity of exposition, and detail of instruction.

D. J. FINNEY

BOOKS TO COME

Bookforecast. *Published monthly by Bibliographia Internationalis Brill, Leiden. Price* 38*s. per annum.*

Only too often one learns of the publication of new books—especially when they are published abroad—long after their first appearance. Although this advance information is available in the advertisements of individual publishers, these are now so numerous—more than 150 publishers of international reputation have already agreed to contribute to this new review—that it is quite impossible to keep oneself informed of all of them. The regular monthly summary provided by *Bookforecast* should prove of considerable value to scientists of all persuasions, as a substantial part of the review is devoted to new books on science, medicine, and technology.

T R.E.

One Story of Radar, *by A. P. Rowe. Pp.* 206, *with* 7 *plates. Cambridge University Press.* 1948. 8*s.* 6*d. net.*

During the war A. P. Rowe was Chief Superintendent of the Telecommunications Research Establishment, and in this book he has written its history from the beginning. T.R.E. was the original home of radar, and, associated as it was with the R.A.F., which made more use of radar than any other service, it became the largest British organization for research in this field. No small share of the responsibility for the enormous success of T.R.E. must be attributed to the author, whose personality impressed itself so strongly on the establishment. Although not himself a research scientist, Rowe provided a focus for the efforts of the brilliant team he collected, and his strong sense of the proper role of science in war, and of the intimate relationship which should exist between scientist and soldier, did much to direct these efforts into the right channel and to ensure their fruitful application.

As the author points out in his preface, this book does not set out to be a history of radar, but as the history of a vital war establishment it is a fascinating study—the more because in it the author reveals much of himself. It is written in so personal a vein that it will perhaps chiefly interest the thousands who were at some time associated with T.R.E. or worked there; to them especially it will recall something of the atmosphere of this famous establishment which did so much to make victory possible.

J. G. KENDREW

VELOCITY-MODULATED TUBES

Velocity-Modulated Thermionic Tubes, *by A. H. W. Beck. Pp. x + 180, with* 56 *diagrams. University Press, Cambridge.* 1948. 15*s. net.*

This book is the fourth of the Modern Radio Technique series, to whose reputation it will add. Like the other books, it describes developments made during the war, largely under conditions of secrecy, and though much of the material has by now been published, a compact and informative *résumé* such as this will prove very useful, both for information and for reference.

A fairly thorough treatment of the theory of energy interchange between electron beam and electromagnetic field forms the backbone of the book, but the author has taken care that the physical action of velocity-modulated tubes is not obscured by the mathematics. The factors governing the practical performance of the various kinds of tubes (of which the klystron and reflex klystron are at the present time the most important) are discussed at length, and the principles of successful design are developed. In this the author has drawn upon his own experience, giving practical examples of design calculations for tubes to meet specific requirements; several tables and graphs of essential data are provided.

Description of practical construction and manufacture is not given, and though there is a chapter in which some details of the design of the component parts and assembly are discussed, no dimensioned diagrams or photographs are included. The book is very clearly printed and easy to read.

B. M. CROWTHER

Notes on contributors

W. H. PEARSALL,
D.Sc., F.R.S.,

Born at Stourbridge (Worcestershire) in 1891, he was educated at the Ulverston Grammar School and at the University of Manchester. After war service during 1914–18 he became, in 1921, Reader in Botany at the University of Leeds. In 1927 he was Exchange Professor at Cornell University and afterwards, during the first four years from its initiation, Honorary Director of the Freshwater Biological Laboratory at Wray Castle. Later he became Professor of Botany at Sheffield University. Since 1945 he has been Quain Professor of Botany at University College, London. He has been Secretary of the Society for Experimental Biology and of the Freshwater Biological Association and President of the British Ecological Society. In a forthcoming book he writes about *Mountains and Moorlands*. He was for ten years editor of the *Journal of Ecology* and now edits the *Annals of Botany*.

HARRIETTE CHICK,
C.B.E., D.Sc., Hon. D.Sc.,

Is a Fellow of University College, London, and a member of the staff of the Lister Institute of Preventive Medicine. She was educated at Notting Hill High School, Bedford and University Colleges, London, and at the Universities of Vienna and Munich. From 1919 to 1922 she was engaged in nutritional research in Vienna. In 1932 she was appointed Oliver Sharpey Lecturer by the Royal College of Physicians.

W. P. K. FINDLAY,
D.Sc., A.R.C.S., D.I.C., A.I.C.T.A.,

Was born in 1904 and was educated at Sevenoaks School and the Imperial College of Science and Technology, London. After graduating at London University in 1924 he worked for a year with Professor P. Groom on decay of aircraft timber.

In 1927 he was appointed Mycologist at Forest Products Research Laboratory, and has since made an extensive study of the wood-rotting fungi, with particular reference to their physiology, on which he has published numerous papers. He is joint author with K. St G. Cartwright of the recently published textbook *Decay of Timber and Its Prevention* (H.M. Stationery Office). From 1937 to 1945 he was Secretary of the Association of Applied Biologists, and he has been one of the secretaries of the Biological Council since its inception. He is President of the British Mycological Society for the present year.

S. G. HOOKER,
O.B.E., B.Sc., D.Phil., F.R.Ae.S.,

Was born in 1907, and received his scientific education at the Imperial College, London, and Brasenose College, Oxford. On leaving Oxford in 1936 he joined the scientific staff of the Admiralty and worked in the Ballistics Department of Woolwich Arsenal on the development of anti-aircraft rockets. In 1938 he joined the staff of Rolls-Royce Ltd., and in 1943 was appointed Chief Engineer of the Rolls-Royce Works at Barnoldswick, Lancashire, leading the group of engineers who were responsible for the development of the Whittle jet engines, including the famous Rolls-Royce Derwent V and Nene engines. He was awarded the O.B.E. in 1946 for his part in helping to secure the world's speed record with the Gloster Meteor aircraft. He joined the staff of the Engine Division of the Bristol Aeroplane Company Limited in January 1949.

J. W. HUNKIN,
O.B.E., M.C., M.A., D.D.,

Since 1935 has been Bishop of Truro, where he was born in 1887. He was educated at the Leys School, Cambridge, and at Gonville and Caius College, Cambridge. His university career was specially distinguished, for he was not only classed as a wrangler in the mathematical tripos, but obtained first-class honours in theology. He served as Chaplain with the Twenty-ninth Division in the war of 1914–18, and was awarded the M.C. and bar, and later the O.B.E.

H. S. HOLDEN,
D.Sc., F.R.S.E., F.L.S.,

Was born in 1887 and was a student at Manchester University, where he was Platt Exhibitioner and Leo Grindon Prizeman. He graduated in 1909, and was appointed Lecturer in Botany at University College, Nottingham, in the same year. He served with the Royal Navy in the 1914–18 war as bacteriologist. He was appointed Senior Lecturer in Botany and Head of the Sub-department of Industrial Bacteriology at University College, Nottingham, in 1919, and Professor of Botany there in 1929. He was Recorder, Section K, of the British Association 1930–3, and became Director of the East Midlands Forensic Science Laboratory in 1936. In 1946 he was made Director of the Metropolitan Forensic Science Laboratory.

F. A. PHILBRICK,
M.A.,

Was born in England in 1903 and was educated at Wellington College and at Balliol College, Oxford, where he was a scholar and took first-class honours in chemistry in 1925. After serving with Lever Brothers Limited in London, Vienna, and Budapest, he taught chemistry and physics at Clifton College and Rugby School until 1939, with a year on leave in America in 1934–5. In 1939 he settled in the United States, and became an American citizen in 1945. He now teaches English at St Paul's School, Concord, N.H.

A. R. MILLER,
M.A., Ph.D.,

Was born in Melbourne (Australia) in 1915 and was educated at Scotch College, Melbourne, and the Universities of Melbourne (Ormond College) and Cambridge (Gonville and Caius College). His research has been mainly in the fields of statistical mechanics and thermodynamics; he has published a number of papers on adsorbed monolayers, the theory of solutions, co-operative phenomena, and low-temperature physics. During the war of 1939–45 he was engaged on special duties with the Royal Air Force, and at its close he was scientific adviser to the Commander-in-Chief of the British component of the Allied Air Forces in the South-West Pacific Area. After the end of the war he returned to Cambridge as an Imperial Chemical Industries Fellow and is now working at the Royal Society Mond Laboratory on the problems of low-temperature physics. He is also continuing his work on adsorbed monolayers and the theory of solutions.

Made and printed in Great Britain at THE KYNOCH PRESS, *Witton, Birmingham, 6, for the publishers*
IMPERIAL CHEMICAL INDUSTRIES LIMITED, *London, S.W.1*